AD-755 923

CONTACT RELIABILITY SCREENING

R. E. Schafer, et al

Hughes Aircraft Company

Prepared for:

Rome Air Development Center

December 1972

DISTRIBUTED BY:

NTIS
National Technical Information Service
U. S. DEPARTMENT OF COMMERCE
5285 Port Royal Road, Springfield Va. 22151

UNCLASSIFIED

Security Classification

DOCUMENT CONTROL DATA - R & D

(Security classification of title, body of abstract and indexing annotation must be entered when the overall report is classified)

1. ORIGINATING ACTIVITY (Corporate author) Hughes Aircraft Company Systems Effectiveness Department Box 3310, Fullerton CA 92634	2a. REPORT SECURITY CLASSIFICATION UNCLASSIFIED 2b. GROUP N/A

3. REPORT TITLE

CONTACT RELIABILITY SCREENING

4. DESCRIPTIVE NOTES (Type of report and inclusive dates)

Final Report - January 1971 - August 1972

5. AUTHOR(S) (First name, middle initial, last name)

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6. REPORT DATE	7a. TOTAL NO. OF PAGES	7b. NO. OF REFS
December 1972	~~144~~ 157	0

8a. CONTRACT OR GRANT NO. F30602-71-C-0148 Job Order No.: 55190245	9a. ORIGINATOR'S REPORT NUMBER(S) None 9b. OTHER REPORT NO(S) (Any other numbers that may be assigned this report) RADC-TR-72-326

10. DISTRIBUTION STATEMENT

Approved for public release; distribution unlimited.

11. SUPPLEMENTARY NOTES	12. SPONSORING MILITARY ACTIVITY
RADC Project Engineer: Donald W. Fulton (RBRS) AC 315 330-4037	Rome Air Development Center (RBRS) Griffiss Air Force Base, New York 13441

13. ABSTRACT

This Final Report is the result of a study performed for RADC under Contract F30602-71-C-0148.

The objectives of this study were to

1) to determine if a relationship exists between relay intermodulation products and constriction resistance, on the one hand, and relay life, on the other, and to

2) quantify the relationship if it exists.

It turns out that both I.M. products and constriction resistance are related, statistically, to relay life although the measurement of constriction resistance had a destructive effect on the contacts and hence, on relay life. However, I.M. products measurement made early in life, on both button and bifurcated type contacts, is a good predictor of relay life. These results were obtained at accelerated operating conditions.

DD FORM 1 NOV 65 1473

I-a

UNCLASSIFIED

Security Classification

UNCLASSIFIED

Security Classification

14. KEY WORDS	LINK A		LINK B		LINK C	
	ROLE	WT	ROLE	WT	ROLE	WT
Nondestructive Tests Accelerated Tests Relay Life Tests						

UNCLASSIFIED

Security Classification

SAC--Griffiss AFB NY

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I-C

FOREWORD

This Final Report describes a study performed by Hughes Aircraft Company, Systems Effectiveness Department, Box 3310, Fullerton, California, under contract F30602-71-C-0148, Job Order Number 55190245, for Rome Air Development Center, Griffiss Air Force Base, New York. Mr. Donald W. Fulton (RBRS) was the RADC Project Engineer for the study, which took place between January 1971 and August 1972.

This report has been reviewed by the RADC Information Office (OI) and is releasable to the National Technical Information Service (NTIS).

This technical report has been reviewed and is approved.

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EVALUATION

1. The purpose of this study was to determine experimentally the correlation between constriction resistance measurements (CR), nonlinear intermodulation products (IM), and contact life. If correlation was found, the feasibility of nondestructive reliability screening was to be investigated.

2. Within the limitations described in the report, strong correlation has been found to exist between contact life and both CR and IM. CR as employed in this study was found to reduce life, that is, destructive to a degree. The use of IM as the basis for a nondestructive reliability screen for contact devices has been found to be feasible. The significance of this finding lies in the ability of the method to predict the expected life of contact devices on a part by part basis which heretofore has not been possible. The method requires that two IM measurements be made, one at zero actuations and the second after some number of "burn-in" actuations. Further work is required to establish the optimum "burn-in" for stress conditions other than those imposed in this study. This effort supports RADC technology plan TPO 16 - Reliability, paragraph 3.15.5.1.3, Nonelectronic Devices.

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0.0 SUMMARY

The purpose of this study is to investigate the relationship between Intermodulation Products and Constriction Resistance, on the one hand, and relay life, on the other, and if a relationship exists, quantify it. Both bifurcated (Manufacturer B) and button (Manufacturer C) contacts were considered at both accelerated and normal test conditions.

Several interesting results were obtained. It was discovered that both I.M. products and constriction resistance are good indicators of relay life. For the accelerated test conditions, linear regression models (linear in the I.M. and constriction resistance measurements) fitted well with the dependent variable being the natural logarithm of relay life. This type model fitted both the "TYPE B" (bifurcated) and "TYPE C" (button) contact relays. To use the models it is required that measurements of I.M. products and constriction resistance be made slightly (10-20%) into the relay operating life period. In the case of I.M. products only one measurement (and an initial measurement) need be made. In the case of constriction resistance this was not possible (i.e., only one measurement taken early in the relay life). For constriction resistance, measurements were required initially and at the 1%, 5%, 10% life points for both types of relays. In fact, it was discovered that the physical act of making the constriction resistance measurements, for both types of contacts, has a destructive effect on the relay contacts and hence, on relay life. While, statistically speaking, constriction resistance measurement gives slightly better results than I.M. products as a predictor of relay life this was due, in part, to the fact that the constriction resistance measurement itself was contributing to relay life: by shortening it. Thus, constriction resistance is unsuitable as a nondestructive test for relay life. At least, it is unsuitable in the manner in which it was measured in this investigation. Attempts to fit failure distribution to the lifetimes observed at accelerated conditions were unsuccessful. The "popular" families were tried: Weibull, Gamma and Lognormal.

For the normal test conditions only about one-fifth the number of relays were tested as were tested for the accelerated conditions and the results of the analysis were inconclusive.

1.0 INTRODUCTION

BACKGROUND AND PURPOSE OF THE STUDY

For many parts in use at the present time, the quality or reliability characteristics of interest are not susceptible to measurement without destroying the part. For nonelectronic parts this is particularly true since a prime reliability characteristic is part lifetime and to measure lifetime is usually to destroy the part. For this reason, nondestructive tests (hereafter NDT) for nonelectronic part reliability assessment have received a good deal of study. One of the more definitive works in the area of NDT is: RADC-TR-69-209, Nondestructive Determination of Nonelectronic Part Reliability. One of the nonelectronic parts receiving study in the aforementioned report was relays; relays being high usage items and, consequently, their reliability is of prime concern. In RADC TR-69-209 it was suggested that the magnitude of the intermodulation products (hereafter I.M. products) and/or the constriction resistance of the contacts might be good measures of contact quality and, hence, relay lifetime. The purpose of this present study then, in general terms, is to determine if a relationship exists between relay life and the magnitude of the I.M. products and constriction resistance and, if it exists, quantify the relationship.

The relay selected for study is the MS757/10-33: hermetically sealed, DPDT, high level with a contact current of 2 amps, d.c. and a coil voltage of 26 volts d.c. This type relay has previously been studied (with regard to the design of accelerated test) and the results reported in RADC-TR-69-179, Accelerated Test Technology/Test Program for Nonelectronic Parts; RADC-TR-66-425, Accelerated Reliability Testing for Nonelectronic Parts; and RADC-TR-65-46, Accelerated Reliability Test Method for Mechanical and Electromechanical Parts.

In order to investigate the relationship (between the independent variables I.M. products and contact constriction resistance, on the one hand, and the dependent variable, relay life, on the other hand) over as broad a range as possible, within limited funds, it was decided to study two types of relay contacts: bifurcated and button. The relay selected for the bifurcated configuration will be called the Type B relay and the button contact relay will be called the Type C relay throughout this report. Perhaps, at this point, it should be emphasized that the purpose of the study is to investigate relationships and <u>is not</u> to determine (or otherwise, comment on) the relative or absolute <u>reliabilities</u> of the Type B and Type C relays. Again, to maintain some range of applicability, it was decided to conduct the tests at two test conditions. At the accelerated test conditions the relays were run at 6 amps, 25°C and 60 hz. The normal conditions were 3 amps, 25°C and 1 hz. The accelerated conditions were established from the results of the previously mentioned RADC funded studies. In the belief that the NDT method, if useful, would be applied at accelerated test conditions and because of time limitations the relative numbers of relays tested at accelerated conditions to normal conditions was 5 to 1. That is, 200 relays were tested at accelerated conditions and 41 relays at normal conditions. Originally, it had been planned to have 50 relays at normal conditions but because the "normal" relays were slow in failing, time dictated that only 41 be tested. Generally, what has been done is to place relays (Type B and Type C) on test at one of two (accelerated or normal) test conditions. The relays then received, periodically throughout its lifetime either I.M. products or constriction resistance measurements (not both on the same relay). The relay life was then recorded and used as the "dependent" variable. The quotes on dependent is to indicate in some (regression) analyses we used functions of the relay life as the dependent variable, e.g., we tried logarithm of the lifetime.

This report is divided roughly into two parts. The first part and main body is comprised of Sections 2.0, 3.0, 4.0 and 5.0. Sections 2.0 through 4.0 give a summary and the useful findings with regard to the relay tests (2.0), the statistical analyses (3.0), and the failed part analyses (4.0). Section 5.0 contains recommendations for further study. The second part of the report is the Appendix (Section 6.0) which gives much more detail on all aspects of the study. For example, the experimental design is described in detail; the test set-up is described in detail. Another example of the relationship of the Appendix to the main body is the statistical analyses. All statistical analyses and models tried are described in the Appendix while only the useful results appear in the main body.

2.0 SUMMARY OF THE RELAY TESTS

2.1 TEST CONDITIONS, DEFINITION OF FAILURE

2.1.1 TEST CONDITIONS

Two types of relays were selected for this study program. The primary factor involved in the selection was to subject two different types of contacts to the stresses applied in the tests. One relay selected for the program was constructed with bifurcated contacts and identified as Type B. The other type relay contained button type contacts, and was identified as Type C. One normally open and one normally closed contact pair were tested in each relay. The relays contain two complete switching circuits. To eliminate interaction betweeen the contact pairs due to excessive material transfer or welding, the contact pairs tested were selected from separate switching circuits within the relay. A total of 200 relays (100 each type) were subjected to accelerated life test conditions of 6 amperes load current and a 60 hz. actuation rate with a 25°C ambient temperature. An additional 41 relays (20 Type B and 21 Type C) were subjected to life test conditions of 3 amperes load current and a 1 hz. actuation rate with a 25°C ambient temperature.

The relays (in groups of 5) were subjected to the life test until failure.

2.1.2 DEFINITION OF FAILURE

A failure was defined as three misses for any individual contact as described in Paragraph 6.4.1.

2.2 RELAY MEASUREMENTS: INITIAL AND DURING TEST

The initial parameters measured were coil resistance, contact resistance, insulation resistance, pickup voltage, dropout voltage, operate time, release time and contact bounce. These parameters were measured prior to constriction resistance and I.M. products measurements and the life test. The test methods used for measuring the parameters are described in detail in Paragraph 6.2. Constriction resistance and I.M. products measurements were made on the appropriate relays as outlined in Table 6.1.1 just prior to the life test and at 17 periods during the life test. Figure 6.4.2.1 gives the distribution of measurement periods (in cycles) for the normal and accelerated conditions. The test methods used for measurement of I.M. products and constriction resistance are detailed in Paragraphs 6.4.3 and 6.4.4 respectively.

2.3 TEST SETUP, DATA RECORDING

The life tests were performed with the Hughes Automatic Relay Contact Monitor and Life Test Set. A significant feature of this set, especially because of the criticality of the test schedule, was that the lower actuation rate of 1 hz. was performed automatically on a 24-hour basis and provided photographic records of failure data.

Basically, the contact failure detection system of the Test Set consists of four circuits that activate the data display and camera circuits by means of pulse type information. Data was displayed by the illumination of lamp circuits in view of a camera. Camera trigger pulses were channeled to a digital storage circuit to prevent a data pile-up and possible loss of data during the actuation time of the camera.

The Test Set has provisions for ten contact circuits. A normally open and a normally closed pair of contacts were tested in each relay, therefore, two contact circuits required monitoring for each relay. A total of five relays were tested simultaneously. There was no possibility of reversed polarity since the holding fixture in the test set up permitted hooking the relay up only one way. A potential of 26.5 V.D.C. was applied to the coils through the contacts of a mercury wetted contact chopper type relay. Actuation rates were one cycle per second and sixty cycles per second. The actuation duty cycle was approximately fifty percent. The load bank used to limit the contact current contained non-inductive resistors and was forced air cooled for current stability.

Data acquisition was accomplished photographically with a 35-mm impulse type recording camera. A panel with three indicators, for each of the ten channels, represents first, second and third relay contact miss for each of the ten relay contact circuits. The camera recorded the status of the contact miss display, real time and accumulated relay actuations each time a new miss occurred. The processed film presents a permanent and accurate record of all the events of the test.

3.0 STATISTICAL ANALYSES AND RESULTS

This section describes the statistical analyses performed in this study and summarizes the results obtained. Subsections 3.1 and 3.2 summarize the results of the regression analyses and goodness-of-fit tests, respectively. A detailed description of these analyses can be found in the Appendix of this report (Subsection 6.5). The description of the analysis in Subsection 3.3, "Comparison of Test Conditions," is complete as written, and so is not covered in the Appendix.

3.1 DESCRIPTION OF THE REGRESSION ANALYSES

Regression analysis of the relay test data was the principal method used in this study to investigate the relationships between constriction resistance (C.R.) measurements and relay life and between intermodulation (I.M.) products and relay life. Table 3.1.1 indexes the 8 blocks of data for which regression analyses were run. The last column gives the total number of regression models investigated in each of the 8 blocks. These models were generated by using 20 different types of regression models, and for each type of model using different possible numbers of I.M. or C.R. measurements as independent variables. In all models the dependent variable Y denotes relay lifetime defined as the minimum of the number of cycles to third miss of the N.O. contact pair and the number of cycles to third miss of the N.C. contact pair. A complete description of all the regression models investigated is given in Section 6.5.1.1 of the Appendix.

A multiple regression computer program was used to analyze each of the blocks using the selected models. The program computes coefficients of the regression equation, the multiple correlation coefficient R, the observed value of the statistic for the F-test, $F_{OBS.}$, and other important statistics of the multiple regression analysis. A complete description of the computer program and its outputs is presented in Section 6.5.1.2 of the Appendix.

The outputs of the regression runs were analyzed in order to determine whether there was a relationship between relay life and I.M. or C.R. measurements, and if so, to select a "best" model for each of the 8 blocks. The most important criterion for the selection procedure was that the value of $F_{OBS.}$ be sufficiently high. A high value of $F_{OBS.}$ leads to rejection of the null hypothesis that there is no relationship between relay life and I.M. or C.R. measurements. That is, a high value of $F_{OBS.}$ indicates that there is a relationship, and that it is explained by the model. Another criterion for the selection of a "best" model is that R', the multiple correlation coefficient adjusted for degrees of freedom, have a sufficiently high value. A high value of R' indicates that the data fits the regression equation well. A complete description of the criteria used to select the "best" models is given in Section 6.5.1.3 of the Appendix.

TABLE 3.1.1 INDEX OF DATA BLOCKS

BLOCK NO.	ACCELERATED(A) OR NORMAL(N)	RELAY TYPE	QUANTITY MEASURED	NO. OF RELAYS IN BLOCK	NO. OF REGRESSION MODELS INVESTIGATED
1	A	B	I.M.	50	164
2	A	B	C.R.	50	124
3	A	C	I.M.	50	268
4	A	C	C.R.	50	204
5	N	B	I.M.	10	80
6	N	B	C.R.	10	60
7	N	C	I.M.	10	44
8	N	C	C.R.	12*	44

*Only 11 relays were tested completely, and the 12th relay was damaged during test. However, one of the contact pairs had already failed before damage to the other contact pair occurred, so that enough data was available on the 12th relay according to the definition of relay life used.

3.1.1 SUMMARY OF RESULTS

The next 4 sections (3.1.2 through 3.1.5) summarize the results of the regression analyses for each of the 8 blocks. From these results, some general conclusions about the relationship between relay life and I.M. or C.R. measurements can be made. The conclusions are as follows:

1. For all the relays tested at accelerated conditions, the relationship between relay life and I.M. or C.R. measurements can be well described by models of the form

$$Y = \exp(c_0+c_1X_1+c_2X_2 + \dots + c_kX_k + \epsilon),$$

where Y denotes relay life and $\{X_j, j=1, \dots, k\}$ denotes the first k measurements of the quantity being measured (I.M. or C.R.), X_1 being the initial measurement taken before the start of the test. The error ϵ is presumed to be a normally distributed random variable with mean 0.

2. For the relays tested at normal conditions, regression models were fitted in only 3 out of the 4 blocks. Unlike the accelerated tests, there was no uniformity of results among the 3 blocks. The problem was that the sample sizes used (10 relays/block) were too small to determine the true relationship between relay life and I.M. or C.R. measurements. If larger sample sizes were used (say 50 relays /block as in the accelerated tests), then a general form of the "best" model would probably have been discovered.

3. C.R. measurements form a better basis for predicting relay life than do I.M. measurements. As Table 6.5.1.4.1 in the Appendix shows, all of the fitted regression equations having C.R. measurements as independent variables fit "better" (as judged by the significance level of $F_{OBS.}$) than all of the fitted regression equations having I.M. measurements as independent variables.

4. For the relays tested at accelerated conditions, the relationship between relay life and I.M. measurements can be described by models of the form

$$Y = \exp(c_0+c_1X_1+c_kX_k + \epsilon).$$

The above model fits about as well as the model given in Conclusion 1, and has the practical advantage that only an initial I.M. reading, X_1, and one later I.M. reading, X_k, need be taken. Comparisons of regression analyses show that the Kth reading should be taken 10-20% into the estimated relay life. The previous model required k, as opposed to only 2, I.M. readings.

An analogous conclusion could not be made for the accelerated models using C.R. measurements. A complete discussion of the analyses of the models using only an initial and a later measurement is found in Section 6.5.1.5 of the Appendix.

3.1.2 TYPE B RELAYS: RESULTS OF ANALYSES AT ACCELERATED CONDITIONS

To investigate the relationship between I.M. measurements and the lifetime of Type B relays tested at accelerated conditions, 164 regression models were investigated. Table 3.1.2.1 summarizes the results of the regression analysis for the model that fitted best according to the selected criteria. The table gives the number of data points used as 18, because even though 50 relays were put on test, only 18 of them survived to the sixth I.M. reading, and hence, only data from these 18 relays could be used to fit the model. Table 3.1.2.1 gives the following important statistics from the regression analysis:

- The multiple correlation coefficient (R).
- The multiple correlation coefficient adjusted for degrees of freedom (R′).
- The standard error of the estimate.
- The standard error of the estimate adjusted for degrees of freedom.
- The F-ratio for the sum of squares due to regression ($F_{OBS.}$).
- The fitted regression equation.

The value of $F_{OBS.}$, 2.32, has significance level α = .10. That is, 2.32 is the critical value of the F-test of the null hypothesis that relay life has no relationship to I.M. measurements. In general, for high values of $F_{OBS.}$ (and hence, for low values of α), the evidence is strong that the model fits.

Table 3.1.2.2 summarizes the analysis of the regression model obtained by using only the first and last I.M. measurements of the model in Table 3.1.2.1. The value of $F_{OBS.}$, 3.49, has significance level α = .06, which shows a good fit of the model $Y = \exp(C_0+C_1X_1+C_KX_K+\epsilon)$. Therefore, both of the models presented are good approximate representations of the true relationship between I.M. measurements and Type B relay life under accelerated conditions.

Table 3.1.2.3 summarizes the results of the regression analysis for the best model (out of a total of 124 models investigated) explaining the relationship between C.R. measurements and relay life for Type B relays tested under accelerated conditions. For this model the signficance level of $F_{OBS.}$ is less than .0005.

TABLE 3.1.2.1

Block No.	1
Test Conditions	Accelerated
Relay Type	B
Independent Variables, X_j	I.M. Products
Number of Measurements, k	6
Number of Data Points, n	18

Multiple Correlation Coefficient	.74706
Adjusted for Degrees of Freedom	.61153
Standard Error of the Estimate	.45266
Adjusted for Degrees of Freedom	.53877
F-Ratio for Sum of Squares Due to Regression	2.3154

Regression Equation:

$$Y = \exp(10.1339 - 1.6114X_1 + 2.9140X_2 - 9.3429X_3 - 4.1576X_4 + 8.1096X_5 + 4.7862X_6 + \epsilon).$$

TABLE 3.1.2.2

Block No.	1
Test Conditions	Accelerated
Relay Type	B
Independent Variables, X_j	I.M. Products
Number of Measurements	2
Number of Data Points, n	18

Multiple Correlation Coefficient	.56363
Adjusted for Degrees of Freedom	.52443
Standard Error of the Estimate	.48167
Adjusted for Degrees of Freedom	.49650
F-Ratio for Sum of Squares Due to Regression	3.4919

Regression Equation:

$$Y = \exp(12.0714 - 4.4760X_1 + 4.3881X_6 + \epsilon).$$

TABLE 3.1.2.3

Block No.	2
Test Conditions	Accelerated
Rel·· Type	B
Independent Variables, X_j	C.R. Measurements
Number of Measurements, k	4
Number of Data Points, n	15

Multiple Correlation Coefficient	.81856
Adjusted for Degrees of Freedom	.79882
Standard Error of the Estimate	1.25876
Adjusted for Degrees of Freedom	1.31826
F-Ratio for Sum of Squares Due to Regression	15.2305

Regression Equation:

$$Y = \exp(8.33180 - .00509X_1 + .00396X_2 + .00523X_3 + .01481X_4 + \epsilon).$$

3.1.3 TYPE B RELAYS: RESULTS OF ANALYSES AT NORMAL CONDITIONS

Table 3.1.3.1 summarizes the results of the analysis for the best of the 80 regression models investigated to find the relationship between I.M. measurements and relay life for Type B relays tested at normal conditions. The value of R' is very high (.95), but the significance level of $F_{OBS.}$ is .34, which is quite inadequate.

To study the relationship between C.R. measurements and relay life for Type B relays tested at normal conditions, 60 regression models were investigated. The best of these regression analyses is summarized in Table 3.1.3.2. The model fits very well, with $R' = .89$, and $F_{OBS.}$ significant at the .07 level.

3.1.4 TYPE C RELAYS: RESULTS OF ANALYSES AT ACCELERATED CONDITIONS

For the case of the Type C relays at accelerated conditions with I.M. measurements, a total of 268 regression models were investigated. Table 3.1.4.1 summarizes the results of the analysis for the best of these models. For this model, the value of $F_{OBS.}$ has a significance level of .08. Table 3.1.4.2 summarizes the results of the model obtained by using only the initial and final I.M. measurements of the model of Table 3.1.4.1. Both models fit the data about equally well. For the latter model, the significance level of $F_{OBS.}$ is .04.

Table 3.1.4.3 summarizes the results of the best of the 204 models investigated to find the relationship between Type C relay life and C.R. measurements, when the relays are tested at accelerated conditions. For this model, $F_{OBS.}$ has a significance level of .03.

3.1.5 TYPE C RELAYS: RESULTS OF ANALYSES AT NORMAL CONDITIONS

To study the relationship between I.M. products and relay life for Type C relays tested at normal conditions, a total of 44 regression models were investigated. Table 3.1.5 summarizes the results of the best of these analyses. Although the value of R' is fairly high (.76), the model is rather inadequate, since the significance level of $F_{OBS.}$ is high (.36).

For the case of Type C relays tested at normal conditions with C.R. measurements, no adequate regression model was found. A total of 44 models were investigated, but they all yielded values of $F_{OBS.}$ with significance levels exceeding .50.

3.2 RESULTS OF GOODNESS-OF-FIT TESTS

An attempt was made to fit failure distributions to each of the 4 blocks of relays tested under accelerated conditions. Fifty observations of relay life (defined as in Section 3.1) were available in each block. Parameters of Weibull, Lognormal, and Gamma distributions were estimated in each block.

TABLE 3.1.3.1

Block No.	5
Test Conditions	Normal
Relay Type	B
Independent Variables, X_j	I.M. Products
Number of Measurements, k	5
Number of Data Points, n	6

Multiple Correlation Coefficient	.98034
Adjusted for Degrees of Freedom	.95009
Standard Error of the Estimate	2.8328×10^5
Adjusted for Degrees of Freedom	4.4791×10^5
F-Ratio for Sum of Squares Due to Regression	6.1717

Regression Equation:

$$Y = 2.7049 \times 10^6 + 1.7707 \times 10^5 x(X_2^2 - X_1^2) + 3.3586 \times 10^6 x(X_3^2 - X_1^2)$$

$$+ 1.0509 \times 10^7 x(X_4^2 - X_1^2) - 1.2489 \times 10^7 x(X_5^2 - X_1^2) + \epsilon.$$

TABLE 3.1.3.2

Block No.	6
Test Conditions	Normal
Relay Type	B
Independent Variables, X_j	C.R. Measurements
Number of Measurements, k	3
Number of Data Points, n	6

Multiple Correlation Coefficient	.91517
Adjusted for Degrees of Freedom	.89271
Standard Error of the Estimate	.32885
Adjusted for Degrees of Freedom	.36765
F-Ratio for Sum of Squares Due to Regression	7.7329

Regression Equation:

$$Y = \exp\left(15.5376 - 4.15998\left(\frac{X_2 - X_1}{X_1}\right) - 4.01936\left(\frac{X_3 - X_2}{X_2}\right) + \epsilon\right).$$

TABLE 3.1.4.1

Block No.	3
Test Conditions	Accelerated
Relay Type	C
Independent Variables, X_j	I.M. Products
Number of Measurements, k	4
Number of Data Points, n	34

Multiple Correlation Coefficient	.49863
Adjusted for Degrees of Freedom	.41653
Standard Error of the Estimate	1.0172
Adjusted for Degrees of Freedom	1.0669
F-Ratio for Sum of Squares Due to Regression	2.3991

Regression Equation:

$$Y = \exp(8.0595 - 7.7088X_1 + 3.0430X_2 - 1.8549X_3 + 6.5706X_4 + \epsilon).$$

TABLE 3.1.4.2

Block No.	3
Test Conditions	Accelerated
Relay Type	C
Independent Variables, X_j	I.M. Products
Number of Measurements	2
Number of Data Points, n	34

Multiple Correlation Coefficient	.48074
Adjusted for Degrees of Freedom	.45507
Standard Error of the Estimate	.99522
Adjusted for Degrees of Freedom	1.0106
F-Ratio for Sum of Squares Due to Regression	4.6591

Regression Equation:

$$Y = \exp(8.1286 - 7.6816X_1 + 7.7040X_4 + \epsilon).$$

TABLE 3.1.4.3

Block No.	4
Test Conditions	Accelerated
Relay Type	C
Independent Variables, X_j	C.R. Measurements
Number of Measurements, k	3
Number of Data Points, n	43

Multiple Correlation Coefficient	.45287
Adjusted for Degrees of Freedom	.40663
Standard Error of the Estimate	.80665
Adjusted for Degrees of Freedom	.82657
F-Ratio for Sum of Squares Due to Regression	3.3542

Regression Equation:

$$Y = \exp(7.20634 - .01335X_1 - .04453X_2 - .02241X_3 + \epsilon).$$

TABLE 3.1.5

Block No.	7
Test Conditions	Normal
Relay Type	C
Independent Variables, X_j	I.M. Products
Number of Measurements, k	3
Number of Data Points, n	5

Multiple Correlation Coefficient	.8257
Adjusted for Degrees of Freedom	.7588
Standard Error of the Estimate	$1.9484\text{x}10^5$
Adjusted for Degrees of Freedom	$2.2499\text{x}10^5$
F-Ratio for Sum of Squares Due to Regression	2.1427

Regression Equation:

$$Y = 4.9691\text{x}10^5 - 8.1201\text{x}10^6 \text{x}\log\left(\frac{X_2 - X_1}{X_1}\right) + 9.0437\text{x}10^6 \text{x}\log\left(\frac{X_3 - X_2}{X_2}\right) + \epsilon.$$

The distribution parameters are defined and the methods of estimation are discussed in Section 6.5.2 of the Appendix.

Chi-square goodness-of-fit tests were carried out with 7 χ^2-cells used in each case. Since, in each case, 2 parameters were being estimated, the Chi-square tests were taken with 4(=7-2-1) degrees of freedom.

Tables 3.2.1 through 3.2.3 give the estimated parameters and the value of the χ^2 statistic for each test. Since the 95th percentage point of the Chi-square distribution with 4 degrees of freedom is 9.49, all 12 tests reject the null hypothesis that the distribution fits the data at the .05 significance level. The conclusion is that lifetimes of relays tested at accelerated test conditions do not have distributions of the form of any of the known families investigated. The true distributions of relay lifetimes are probably too irregular to be represented by any commonly known parametric family.

No attempt was made to find the distribution of lifetimes of the relays tested at normal conditions, since the number of observations (10 relays/block) was inadequate for carrying out Chi-square tests.

A complete description of the goodness-of-fit tests is found in Section 6.5.2 of the Appendix.

3.3 COMPARISON OF TEST CONDITIONS (I.M. PRODUCTS VERSUS CONSTRICTION RESISTANCE)

In carrying out the relay tests at accelerated conditions, it appeared that taking constriction resistance (C.R.) measurements degraded relay performance. This section describes statistical tests that were used to test the difference between the mean lifetimes of the relays on which C.R. measurements were taken and the mean life of those on which I.M. measurements were taken.

Separate tests were made for each of 4 distinct groups of relay data: (1) Type B relays at accelerated test conditions; (2) Type C relays at accelerated test conditions; (3) Type B relays at normal test conditions; and (4) Type C relays at normal test conditions. It is obvious that none of these 4 groups should be pooled. Within each group, lifetimes of the relays with C.R. measurements and those of the relays with I.M. measurements were compared.

Table 3.3.1 gives the sample means and standard deviations of relay lifetimes computed from the test data, where the lifetimes were assumed to be normally distributed. The definition of relay lifetime used here is the minimum of the number of cycles to third miss of the normally open contact pair and the number of cycles to third miss of the normally closed contact pair.

In each of the 4 groups, a t-test was taken of the null hypothesis that the relays with C.R. measurements have the same mean lifetime as those with I.M. measurements. The alternative hypothesis was that the relays with I.M.

TABLE 3.2.1 ESTIMATED WEIBULL PARAMETERS AND RESULTS OF CHI-SQUARE TESTS

Block No.	Test Conditions	Relay Type	Quantity Measured	$\hat{c}$	$\hat{b}$	χ^2*
1	A	B	I.M.	.46896	40149.	15.52
2	A	B	C.R.	.40473	17966.	13.84
3	A	C	I.M.	.67590	3150.6	41.56
4	A	C	C.R.	.80501	2446.5	19.44

TABLE 3.2.2 ESTIMATED LOGNORMAL PARAMETERS AND RESULTS OF CHI-SQUARE TESTS

Block No.	Test Conditions	Relay Type	Quantity Measured	$\hat{\mu}$	$\hat{\sigma}$	χ^2*
1	A	B	I.M.	9.3472	2.5982	13.56
2	A	B	C.R.	8.4313	2.7463	11.88
3	A	C	I.M.	7.3828	1.2263	18.32
4	A	C	C.R.	7.2408	1.1011	11.32

TABLE 3.2.3 ESTIMATED GAMMA PARAMETERS AND RESULTS OF CHI-SQUARE TESTS

Block No.	Test Conditions	Relay Type	Quantity Measured	$\hat{\alpha}$	$\hat{\lambda}$	χ^2*
1	A	B	I.M.	8.289×10^{-6}	.64264	56.96
2	A	B	C.R.	7.720×10^{-6}	.39938	62.28
3	A	C	I.M.	4.492×10^{-5}	.20844	23.64
4	A	C	C.R.	7.553×10^{-5}	.21925	70.96

*The critical value of χ^2 for a .05 level Chi-square test is 9.49.

TABLE 3.3.1 DATA FOR THE COMPARISON OF TEST CONDITIONS

ACCELERATED(A) OR NORMAL(N)	RELAY TYPE	QUANTITY MEASURED	SAMPLE SIZE	SAMPLE MEAN LIFE (IN CYCLES)	SAMPLE STANDARD DEVIATION
A	B	I.M.	50	77,531	97,696
A	B	C.R.	50	51,735	82,695
A	C	I.M.	50	4,641	10,268
A	C	C.R.	50	2,902	6,262
N	B	I.M.	10	1,172,500	769,500
N	B	C.R.	10	908,562	790,532
N	C	I.M.	10	573,121	314,684
N	C	C.R.	12	577,240	271,039

TABLE 3.3.2 RESULTS OF THE t-TESTS

ACCELERATED(A) OR NORMAL(N)	RELAY TYPE	DEGREES OF FREEDOM	t	SIGNIFICANCE PROBABILITY
A	B	98	1.4107	.08
A	C	98	1.0116	.16
N	B	18	.7177	.58
N	C	20	-.0314	.49

measurements have a longer mean lifetime than those with C.R. measurements. The appropriate statistic is

$$T = \sqrt{\frac{n_{IM}\, n_{CR}(n_{IM}+n_{CR}-2)}{n_{IM}+n_{CR}}} \cdot \frac{\bar{Y}_{IM} - \bar{Y}_{CR}}{\sqrt{n_{IM}S_{IM}^2 + n_{CR}S_{CR}^2}} ,$$

where n, $\bar{Y}$ and S denote the sample sizes, sample means and sample standard deviations, respectively, of the subgroups of relays denoted by the subscripts. Large values of T are significant (i.e., lead to rejection of the null hypothesis). Significance probabilities were calculated using the assumption that each subgroup has normally distributed lifetimes, in which case T has a t-distribution with $n_{IM} + n_{CR} - 2$ degrees of freedom under the null hypothesis. Even if the true lifetime distributions are only approximately normal, the computed significance probabilities will be fairly accurate, since the t-test is known to be quite robust.

The results of the 4 t-tests are shown in Table 3.3.2. For the Type B relays at accelerated conditions, there is strong evidence that C.R. measurements shorten relay life, since the null hypothesis is rejected when the significance level is .08 or greater. There is also fairly strong evidence of the degrading effect of C.R. measurements for the Type C relays at accelerated conditions (significance probability of .16). However, for the relays tested at normal conditions, there is no evidence that C.R. measurements degrade relay life, since for both the Type B and Type C relays, the null hypothesis is accepted at any reasonable significance level.

4.0 FAILED PARTS ANALYSIS

4.1 GENERAL RESULTS

In reviewing the failed relays, it was generally found that failures at both normal and accelerated stress conditions occurred by failure mode No. 1 - "Material Transfer from Contact to Blade." Indications of this characteristic were present on almost all specimens.

The relay contact failures, as noted in Figures 6.6.2 through 6.6.5, were attributed primarily to three basic factors.

1. The accelerated life test conditions (high contact current and fast actuation rate).
2. The fast actuation rate (only).
3. The contact alignment.

The actual contact conditions, as reported in Figures 6.6.2 through 6.6.5, are identified to one of the factors above.

CODE NUMBER	FAILURE FACTOR
1	Accelerated life test conditions
2	Accelerated life test conditions
3	Accelerated life test conditions
4	Accelerated life test conditions
5	Contact misalignment
6	See note below
7	Accelerated life test conditions
8	Accelerated life test conditions
9	Accelerated life test conditions

NOTE: The positive cause for failure for Code Number 6 was not determined. However, the probable causes are as follows:

a) Excessive operate and release time

b) Contamination

c) High contact resistance

Of these, the most probable cause would be the operate and release time. It becomes more significant as the actuation rate is increased. The operate and release time has been observed to fluctuate erratically as the actuation rate is increased above 50 hz. The initial test data shows that the Type C relays are more susceptible to this condition.

In reviewing Figures 6.6.2 through 6.6.5, it was noted that for both Code Numbers 5 and 6 a higher percentage was reported for relays with constriction resistance than without constriction resistance. It should also be noted that relays with constriction resistance had a shorter life than relays without constriction resistance.

With regard to misalignment, there was a great deal of non-uniformity of the position of the two legs of the bifurcated contacts in Type B relays. Well over 20% of the parts tested had adjustment differences that were immediately evident in the form of unequal amounts of damage to the contacts. The overload current, however, results in a higher than usual number of early failures because of the small contact surface.

Several Type B relays which had been subjected to constriction resistance testing, were examined under a scanning electronic microscope from 5000 to 8000 magnification. This examination showed that there were round shiny balls on the contact surface. These balls were believed to be silver splatter caused by the high current pulse when making the constriction resistance measurement. This condition could account for the higher reported percentage in Figures 6.6.2 through 6.6.5 under Code Number 6 for those tested with constriction resistance. The silver balls would present a lower surface contact area resulting in a high resistance contact miss. (Note: These silver balls were not noted on relays which were tested without constriction resistance measurements.)

4.2 TYPE B RELAYS

Failure mode No. 6 was noticeably higher with contacts having constriction resistance measurements than with those having I.M. products measurements in both accelerated and normal test conditions. This was due to the early failure rate of the contacts having constriction resistance measurements. No significant difference was noticed between accelerated and normal testing.

Failure mode No. 8 was much greater for contacts tested at accelerated conditions than those tested at normal conditions. This was caused by extreme heating of the contact surfaces due to the high current and rapid actuation rate.

4.3 TYPE C RELAYS

A considerable reduction in failure mode No. 6 was evident in the normal test condition from that observed in the accelerated condition. Contact wear is more uniform during normal condition life testing with a longer useful life. The result is a greater amount of wear over a greater number of actuations with less pernicious effects upon the switching characteristics of the contacts. This condition was verified by the increase in failure mode No. 9 in the normal test condition over the accelerated condition. It was observed that the loss of material from the stationary contact was from vaporization rather than transfer as is evident in a similar increase in failure mode No. 4 in the normal test condition.

5.0 RECOMMENDATIONS

This investigation has shown that a relationship between I.M. products and relay life exists and this relationship has been quantified. Thus, I.M. products measurement presents a possible nondestructive test. The situation for constriction resistance is not so favorable. While a definitive relationship between relay life and constriction resistance exists the measurement technique used tends to cause contact deterioration and thus, it is not a true nondestructive test. Most of the data gathered in this study was at accelerated conditions of relay operations (50 relays per treatment combination*) and this is where the satisfactory results were obtained. It is recommended that I.M. products be further studied, as a nondestructive test, with relays operated at normal conditions. When we say normal conditions we mean possibly even less contact load than the three (3) amps of this study. It is further recommended that each treatment combination of relays be subjected to only one measurement at some period, say p_i, early in life and that various p_i be used for various treatment combinations. In this way the nondestructive test would be easy to use; requiring only one (excepting the initial measurement) measurement on the relay. Also, the "optimum" p_i could be identified. Finally, it is suggested that, in addition to regression analysis techniques linear discriminant analysis techniques be employed as a screening method. That is, instead of trying to predict relay life (from I.M. products measurements) we try to screen the relays (again by I.M. products measurements) into acceptable and nonacceptable classes.

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*A treatment combination is a particular type of relay receiving a particular measurement, i.e., I.M. products or constriction resistance.

6.0 APPENDIX

6.1 DESCRIPTION OF THE EXPERIMENTAL DESIGN

A visual display of the experimental design is given in Tables 6.1.1 and 6.1.2.

TABLE 6.1.1 EXPERIMENTAL DESIGN FOR ACCELERATED TEST CONDITIONS

	Type B	Type C
I.M. Products Measurements	50 relays	50 relays
Constriction Resistance Measurements	50 relays	50 relays

TABLE 6.1.2 EXPERIMENTAL DESIGN FOR NORMAL TEST CONDITIONS

	Type B	Type C
I.M. Products Measurements	10 relays	10 relays
Constriction Resistance Measurements	10 relays	11 relays

In Table 6.1.1 the accelerated conditions refer to a 6 amp. contact load, 25°C temperature and a 60 hz. actuation rate. Thus, at accelerated conditions, 50 Type B relays received I.M. products measurements, 50 Type C relays received I.M. products measurements and so on. The normal conditions represented a 3 amp. contact load, 25°C temperature and a 1 hz. actuation rate. Actually, a total of 50 "normal" tests were planned but time limitations dictated a total of only 41.

The relays were tested in sets of five relays and on each relay the normally open and normally closed contact pairs were monitored until the third miss (miss is defined in Section 6.4). When both the normally open and normally closed contact pairs had achieved three misses (on a given relay) the relay was defined as failed.

To control sources of variability, all the relays from each manufacturer were obtained from one production lot. In addition, the relays were given initial measurements, described in Section 6.2 to make certain all were within specification. Finally, the relays to go on test (5 at a time) were numbered and selected in a random manner from within the desired test cell as given in Table 6.1.1 and 6.1.2.

6.2 INITIAL MEASUREMENTS

The test method used for this program was as follows: All relays were subjected to initial screening tests at room temperature prior to the start of the life test. The screening test parameters measured were: dc coil resistance, contact resistance, insulation resistance, pickup and dropout voltages, operate and release times, and contact bounce. Loads were resistive with an open circuit voltage of 28 VDC. All relay coils were energized with a rated coil voltage of 26.5 VDC.

The tests performed were as follows:

1. Coil Resistance - Using a Wheatstone Bridge.
2. Contact Resistance - By measuring the contact voltage drop at rated test current (3 AMP. D.C.), using a Digital Voltmeter-Ammeter method and by calculating the contact resistance.
3. Operate Time - Using standard oscilloscope procedures.
4. Contact Bounce - Using standard oscilloscope procedures.
5. Release Time - Using standard oscilloscope procedures.
6. Pickup Voltage - Voltmeter and lamp circuit.
7. Dropout Voltage - Voltmeter and lamp circuit.
8. Insulation Resistance - Using a Megohm Bridge.

Primarily, the measurement accuracy of the various test parameters was limited only by the measuring instrument accuracy. Exceptions may have occurred due to the human factor as stated in the following test conditions.

Oscilloscope measurements of operate and release time and contact bounce may vary due to the slight parallax in the oscilloscope screen. The measurement may vary slightly depending on the technician viewing the oscilloscope.

Pickup and dropout voltage measurements may vary with different rates of voltage change. A rate of approximately 0.1 volt per second was used when approaching the critical potential.

The test equipments used for the relay parameter measurement are as follows:

EQUIPMENT LIST (PARAMETER MEASUREMENTS)

Oscilloscope, Tektronix, 535A - H-077926 (Sweep Accuracy: 1-3%)

Pre-Amp, Scope, Tektronix, Type Ca - H-181243 (Amplitude Calibrator Accuracy = 3%)

Digital Voltmeter, Calico, 8101, H-191695 (± 1 digit in last digit)

D. C. Ammeter, Weston, 901, 0-1-5-10A H-34537 (± 0.5%)

D. C. Voltmeter, Weston, 622, 0-30V range - H-47992- (± 0.1%)

Resistance Bridge, Leeds & Northrup, 5300 - 96-00058 (± 0.1%)

D. C. Power Supply, Hewlett Packard, 721A - H-78022

D. C. Power Supply, Hewlett Packard, 721A - H-89573

D. C. Power Supply, Power Designs, 5015A - H-180996

D. C. Power Supply, Universal Electronics, U32-10 - H-212453

Megohm Bridge, General Radio, 544-B,- H-31127 (± 4%)

6.3 DESCRIPTION OF TEST SETUP

6.3.1 GENERAL

The relay life test setup is shown in the block diagram in Figure 6.4.1.1. The test set-up had provisions for actuating, detecting and recording on photographic film the first, second and third contact failure of ten (10) each relay contacts simultaneously. The relays were actuated at rates of 1/sec and 60/sec.

The duty cycle was approximately 50 percent. The electrical load for each relay contact pair consisted of a fixed noninductive wire wound resistor in series with a variable wire wound vernier resistor. The open circuit load voltage was adjusted for 28 VDC, the vernier was adjusted prior to the initiation of the life test for the load test current as specified by the Relay Test Procedure.

A square wave generator was utilized to drive a mercury wetted contact chopper type relay at the desired rate (i.e., 1/sec and 60/sec.).

The coil voltage of approximately 26.5 VDC was applied to each of the relay test specimens through the contacts of this chopper relay. A drive

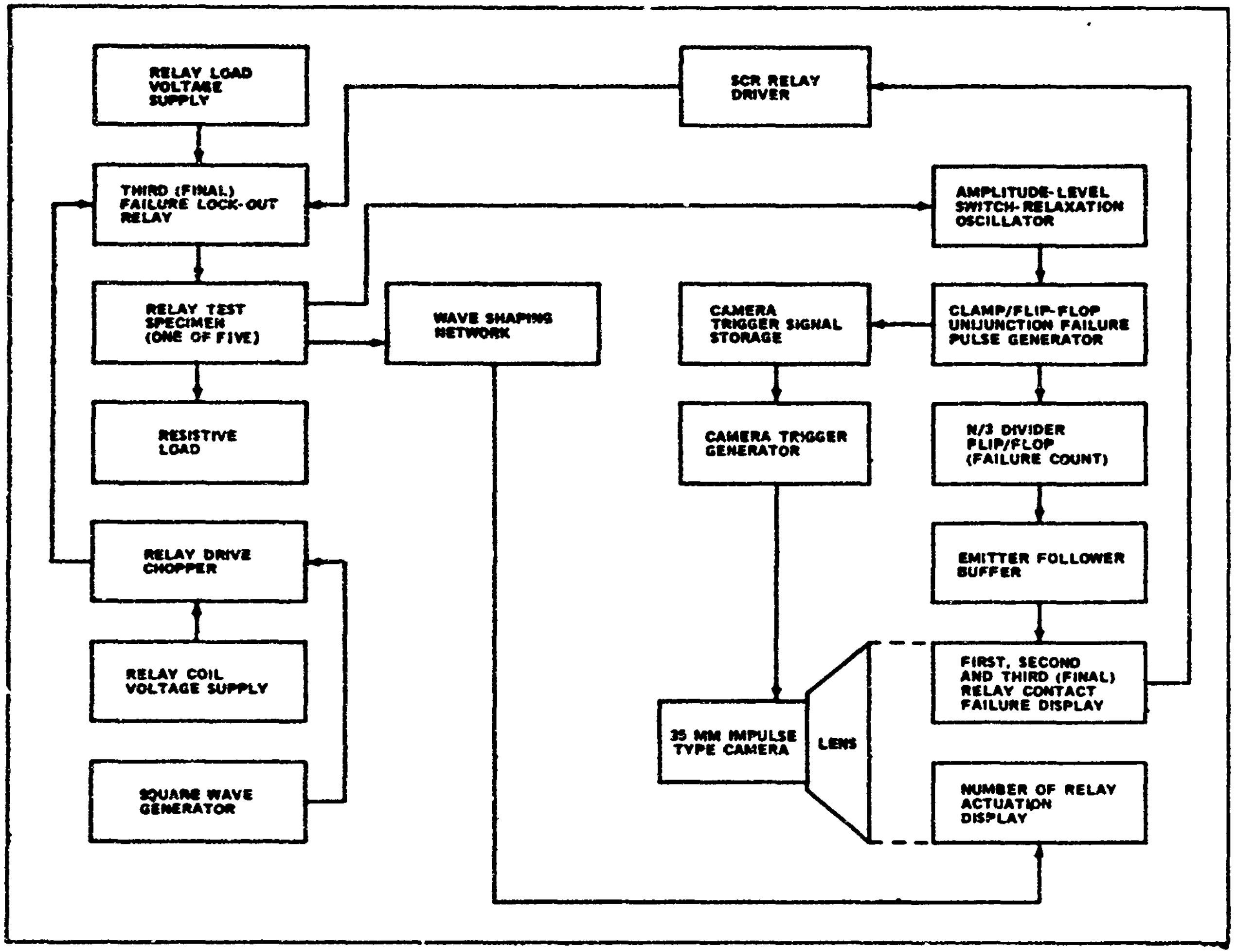


Figure 6.3.1.1 Schematic of Physical Test Method for Crystal Can Relays

signal for the number of relay actuation counters was derived from the chopper relay. A panel with three indicators, representing first, second and third relay contact failures for each of the ten contacts was mounted above the relay actuation counter.

A 35 mm impulse type recording camera was focused on the clock, relay actuation counter and contact failure display. The camera was triggered whenever a contact failure occurred on any or all of the relay test specimens.

The resulting 35 mm film frame displayed the status of the contact failure display, real time and accumulated relay actuations.

The date, test cell number, actuation rate, manufacturer and load current data were written on a writing surface near the clock, so that the camera recorded this information each time a frame was exposed.

6.3.2 CONTACT FAILURE DETECTION

Basically the contact failure detection system consisted of four functional circuits, namely, amplitude switch, relaxation oscillator, Uni-junction failure pulse generator and N/3 divider.

The functions of the system can be explained briefly as follows: The relaxation oscillator period was adjusted to be approximately 75% of one complete switching cycle. If this relaxation oscillator was allowed to free-run, a Uni-Junction circuit was fired at the end of the oscillator's first complete period. This failure pulse entered one count on the respective N/3 divider and also triggered the 35 mm camera.

The camera trigger pulse was applied to a digital storage circuit, which consisted basically of a free-running multi-vibration, flip-flop and emitter follower. This circuit stored the camera trigger pulse.

If a contact failure occurred during the period, where the camera was in the process of recording data (approximately 180 microseconds), then the next "upstate" of the free-running multivibrator would reset the flip-flop and thereby generate an additional camera trigger pulse.

As long as the relay test specimen continued to make and break the contacts at the actuation rate of the relay a potential of 28 VDC was applied across the respective load resistor. This voltage, attenuated to a lower level, was applied to two amplitude switches. One NPN and one PNP computer type transistors were utilized to perform this switching function.

The NPN circuit inhibited the relaxation oscillator from reaching the point where the Uni-Junction circuit would generate a failure pulse as long as a signal voltage was received at the proper relay actuation rate.

The PNP circuit enabled the Uni-Junction circuit to generate a failure pulse whenever the voltage remained for a longer time than the predetermined relay duty cycle time at its input, i.e., welded contacts.

At the time that a failure pulse was generated, a transistor clamping and flip-flop circuit was utilized to reset the relaxation oscillator to zero for the remainder of the cycle and a new cycle began.

The sensitivities of the NPN and PNP amplitude switches were set such that an increase of approximately 35 ohms in the contact resistance of the relay under test would result in a voltage drop sufficient to turn the respective circuit on or off respectively. The N/3 divider circuit counted the generated failure pulses, at the transition from count two to three a trigger pulse was generated.

This pulse was applied to the input of the SCR Relay circuit, the relay was hereby energized and interrupted the load current of the respective relay test specimen. Each of the ten monitoring channels had such a relay. When both relays corresponding to the N/C and N/O contacts of each test relay were energized, the coil drive voltage was interrupted ending the test for that relay.

The primary system power was wired in series with these contacts, when the final relay was energized primary system power was removed, thereby terminating the test.

6.3.3 TEST EQUIPMENT

Item Description	Accuracy
Oscilloscope, Tektronix Model 535A, H-77926	Sweep Accuracy ±3%
Pre-amplifier, Tektronix Model CA, H-181243	Amplitude Accuracy ±3%
Low Frequency Function Generator, Hewlett Packard, Model 202, H-19901	3% Accuracy, 1% Stability
D.C. Voltmeter, Weston Model 622, H-103510	±0.1% of Full Scale.
D.C. Ammeter, Weston Model 901, H-34537	±0.5% of Full Scale
D.C. Power Supply, Perkin Model MR 2432-200, H-15975	
D.C. Power Supply, Perkin Model MR 532-15A, H-33931	

Item Description	Accuracy
D.C. Power Supply, Power Designs Model 5015, H-102143	
D.C. Power Supply, Power Designs Model 5015A, H-180930	
D.C. Power Supply, Power Designs Model 5015A, H-180994	
D.C. Power Supply, Power Designs Model 4005R, H-180883	
D. C. Power Supply, Power Designs Model 4005R, H-180885	
D. C. Power Supply, Dressen Barnes Model 61-102, H-41761	
Electronic Counter, Hewlett Packard Model 524C, H-95876	Totalizing Mode
Relay Contact Failure Detection and Recording System HAC Built	Verified by Above Instruments on Daily Basis.
Load Bank HAC Built	

6.4 RELAY MEASUREMENTS

6.4.1 DEFINITION OF A FAILURE

The failure criteria was defined as three misses. A miss was defined as any actuation during which the following occurred:

1. A contact failed to close within 50% of the normally closed period.

2. A contact failed to open within 50% of the normally open period.

3. A contact closed with a contact resistance greater than 35 ohms.

6.4.2 FREQUENCY OF I.M. PRODUCTS AND CONSTRICTION RESISTANCE MEASUREMENT

Within reasonable limits, the more frequent (and hence the larger number of) the measurements of I.M. products and constriction resistance, hereafter, simply "measurements," the better the chance of obtaining a useful relationship to relay life. It is particularly important to have measurements in the periods of life of highest interest: early life, intermediate life, and late life.

For the purposes of this program the following definitions were made. The early life period is defined as the cycles at which 20 percent of the relays have failed. Put another way, it is the number of cycles such that the probability of relay failure at or before that cycle is 0.20. Similarly, the intermediate period is defined as the cycles between (and including) the 40th and 60th percentiles of the life distribution. Finally, the late life period is defined as the last 80 percent of the life distribution.

It was planned to make five measurements on the N.O. and N.C. contact pairs in each of the early, intermediate, and late life periods. In addition, there was an initial measurement and a measurement at the 30th and 70th percentiles, for a total of 18 measurement periods for each relay: 18 on N.O. pairs and 18 on N.C. pairs. Of course, not all relays received all measurements since they do not all live to completion of the test. Figure 6.4.2.1 on the following page gives the percentiles (in cycles) of the failure distributions at the normal and accelerated conditions. The 18 measurement periods were at the 2nd, 5th, 10th, 15th, 20th, 30th, 40th, 45th, 50th, 55th, 60th, 70th, 80th, 85th, 90th, 95th, 98th percentiles, and an initial measurement.

6.4.3 INTERMODULATION PRODUCTS MEASUREMENT

Figure 6.4.3.2 is a block diagram of the test circuit. The output of the audio oscillator (set at 1 KC) was filtered to minimize the third harmonic content and amplified to the required signal level. The 4 Ohm output of the power amplifier was connected to the contacts under test and a 4.2 Ohm noninductive load resistor in series. The third harmonic voltage generated by the contacts was measured with the HP 302A Harmonic Wave Analyzer. The excitation current was set by adjusting the amplifier input to provide 5 amperes rms. as indicated by an AC ammeter in series with the load.

Third harmonic voltage originating in the power amplifier was monitored and measured daily and/or prior to each cell measurement and was maintained below 5 mv.

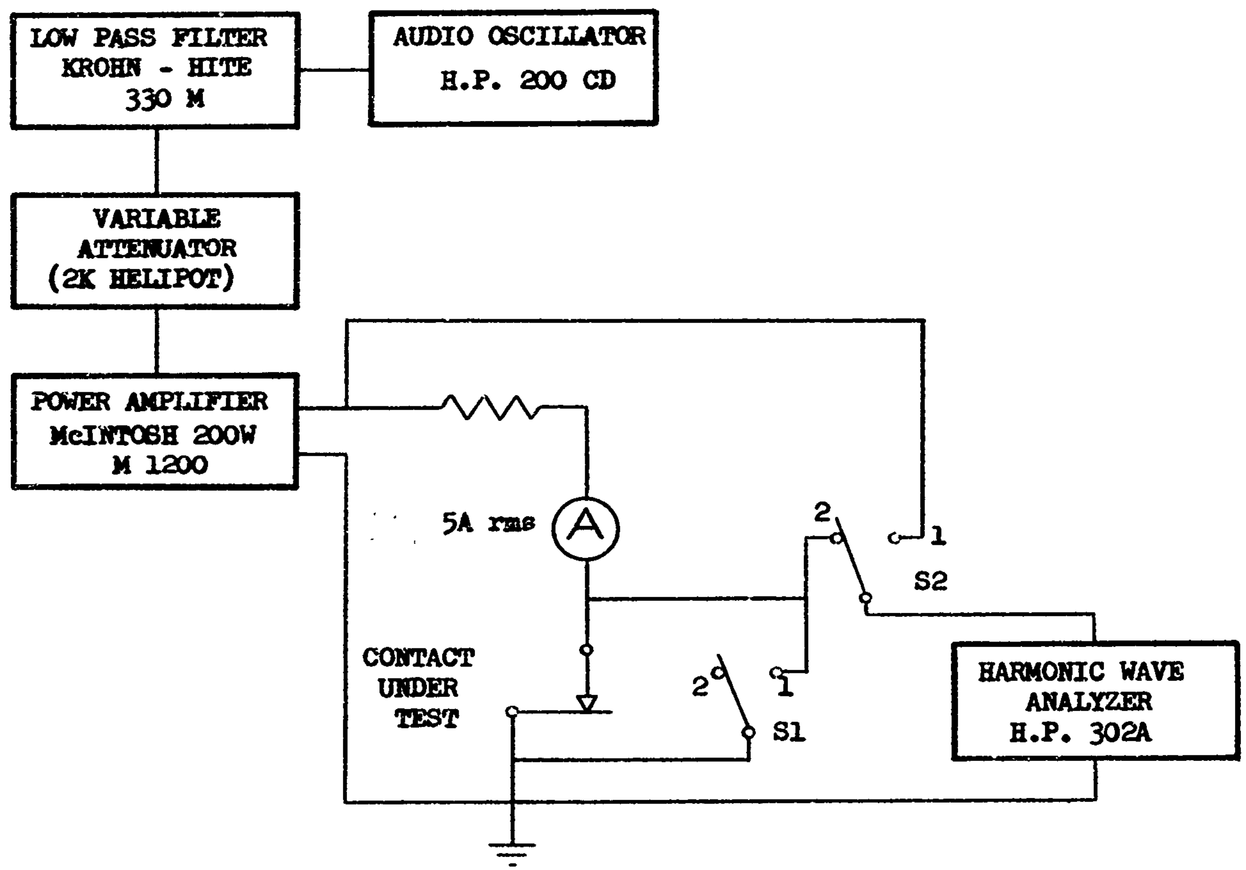
Distortion Constriction Resistance measurement was performed on the relays prior to life test and at the specified measurement points throughout the life test.

6.4.3.1 TEST EQUIPMENT

Item Description	Accuracy
Audio Oscillator, Hewlett Packard Model 200CD, H-48317	Frequency ±2%
Low Pass Filter, Krohn-Hite Model 330M, H-41330	Cut-off Frequencies ±5%
Power Amplifier, McIntosh Model 1200, H-45201	

CONDITIONS	Percentile	3A,25°C,1Hz. B and C	6A,25°C,60 Hz B	C
Initial Measurement		0	0	0
	2nd	18,000	75	350
Early	5th	440,000	500	380
Life	10th	650,000	750	430
Period	15th	725,000	13,400	490
	20th	750,000	75,600	560
	30th	795,000	105,000	720
	40th	835,000	153,000	960
Intermediate	45th	905,000	180,000	1,150
Life	50th	930,000	210,000	1,350
Period	55th	980,000	225,000	1,600
	60th	1,055,000	240,000	2,100
	70th	1,150,000	350,000	3,700
	80th	1,200,000	475,000	9,600
Late	85th	1,275,000	500,000	19,000
Life	90th	1,460,000	585,000	35,000
Period	95th	1,780,000	635,000	88,000
	98th	1,885,000	680,000	107,000

Figure 6.4.2.1 Cycles-at-Measurement for Contact Reliability Screening Program



S1, S2 - POS. 1 SOURCE 3rd HARMONIC

S1, S2 - POS. 2 CONTACT 3rd HARMONIC

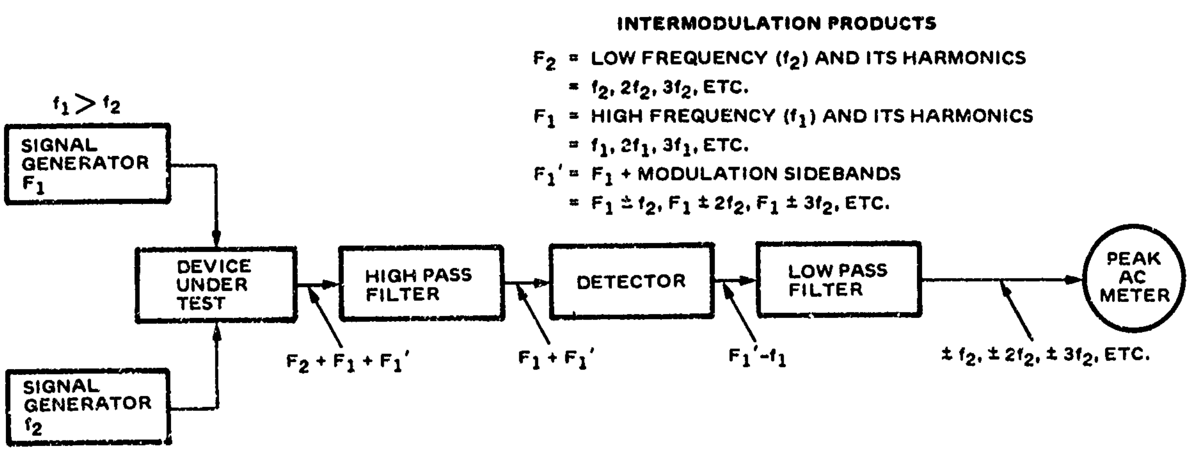
Figure 6.4.3.2 Block Diagram of Intermodulation Products Measurement Circuit

6.4.3.1 TEST EQUIPMENT (Cont'd)

Item Description	Accuracy
Coax Switcher, Jerrold Model FD-30, H-90788	
A.C. Ammeter, Weston Model 904, 520-01209	±0.5% of Full Scale
Wave Analyzer, Hewlett Packard Model 302A, H-89811	Frequency ±(1% + 5 HZ) Amplitude ± 5% of Full Scale

The measurement of intermodulation distortion has for many years been used to assess the non-linearity of audio equipment; however, it has only recently been considered for use as a measure of the health of relay contacts. The classical method of intermodulation distortion measurement is best explained by an examination of a typical test set-up as diagrammed below.

For the sake of simplicity we can consider that the non-linearity of the device under test results in the modulation of the higher frequency f_1 by the lower f_2, and that the high pass filter removes all the fundamental and harmonics of the lower frequency ($F_2 = f_2 + 2f_2 + 3f_2$, etc.). Thus, at the input to the detector, we have the carrier plus its modulation sidebands, plus the harmonics of the carrier and their modulation sidebands, $F_1 + F_1'$. The detection process eliminates the carrier, f_1, and the low-pass filter is selected to remove all harmonics of the carrier ($2f_1$, $3f_1$, etc.) and their modulation sidebands; thus, we are left with only f_2, $2f_2$, $3f_2$, etc. at the input to the meter. This method of measurement is attractive since it eliminates all harmonics of the test frequencies and is thus independent of the purity of the waveform of the signal sources.



When this method of making intermodulation measurements was evaluated for performance, it was determined that the noise ambient was high enough to render the approach impractical.

An examination of the intermodulation components of constriction resistance discloses that a sizeable second harmonic (e_2) of the lower frequency (f_2) is present:

$$e_2 = -\left(\frac{a_3}{4}\right) \text{Sin } 2\omega_2 t$$

where a_3 is the coefficient associated with the i^3 term in the constriction resistance transfer characteristics. Since the second harmonic can be measured using a band-pass filter which restricts the impact of ambient noise to a reasonable level, this method was breadboarded. Evaluation of the breadboard showed that useful and repeatable measurements could be made and this was the selected method.

6.4.4 CONSTRICTION RESISTANCE MEASUREMENT

The 3M Model 8100 Electrical Contact Analyzer was used for measuring Constriction Resistance. Figure 6.4.4.2 is a block diagram of the test circuit. Bias current supplied by a constant current source flows through the contacts under test, causing a deflection of the null meter. The bias current is selected and the null meter deflection is zeroed out. The pulse current is selected and the precision readout of the current amplitude setting is made on a large display meter. A button is depressed to trigger a high current pulse through the contacts while observing the null meter. The pulse current is successively increased through the contacts. A large shift in the null, reading in a high sensitivity range, indicates that critical current has been reached, and a direct reading of Pulse Constriction Resistance is made on the display meter.

6.4.4.1 TEST EQUIPMENT

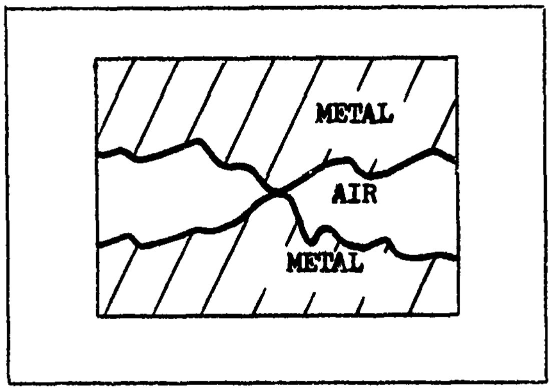
Item Description	Accuracy
Contact Analyzer, 3M Model 8100, H-224182	± 5% Nominal Capability

6.5 STATISTICAL ANALYSES

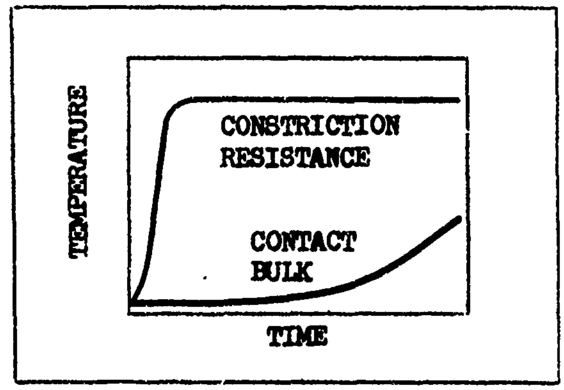
Section 3 of this report briefly describes the statistical analyses performed in this study and summarizes the results obtained. The purpose of this appendix is to present a complete and self-contained account of the statistical analyses leading to the results summarized in Sections 3.1 and 3.2. The descriptions of the analysis in Section 3.3 is complete and needs no further detail.

6.5.1 REGRESSION ANALYSES

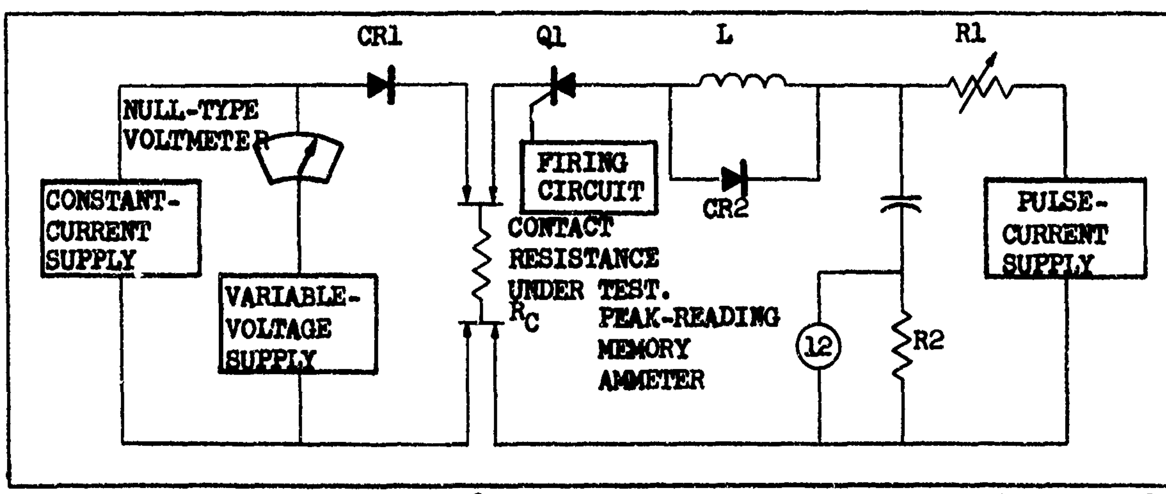
Regression analysis of the relay test data was the principal method used in this study to investigate the relationships between constriction resistance (C.R.) measurements and relay life and between intermodulation (I.M.) products and relay life. This section describes how the regression



Enlarged View of Contact Interface. The actual area of contact is a small fraction of the apparent interface area.



Thermal Response at the Area of Actual Contact. The constriction resistance response is greater and more accelerated than the contact bulk response.



Block Diagram of the 3M Model 8100 Electrical Contact Analyzer. Current pulse is used to measure the constriction resistance.

Figure 6.4.4.2

analyses were planned and carried out, resulting in the selection of models yielding mathematical estimates of the dependence of relay life on I.M. and C.R. measurements. The discussion is divided into 4 subsections. Section 6.5.1.1 describes the range of regression models that were investigated in this study. Section 6.5.1.2 describes the multiple regression computer program that was used to fit the models to the data. Section 6.5.1.3 discusses the criteria that were used in analyzing the output of the computer runs in order to identify the "best" regression models. Finally, in Section 6.5.1.4, the "best" regression equations determined from the analyses are exhibited and discussed.

6.5.1.1 THE REGRESSION MODELS

Table 6.5.1.1.1 indexes the eight blocks of data obtained in this study. In Blocks 1,3,5 and 7, I.M. measurements were taken on the relays, so that the data in these blocks was used to determine the relationship between relay life and I.M. measurements. Similarly, the data in Blocks 2,4,6 and 8 was used to determine the relationship between relay life and C.R. measurements. Data from relays tested under accelerated test conditions can clearly not be pooled with data from relays tested under normal test conditions, nor can data from the two different types of relays be combined. Hence, eight different regression analyses were carried out, one on each block of data.

In all the regression analyses, only one definition of relay lifetime was used: relay lifetime is defined to be the minimum of the number of cycles to third miss of the normally open (N.O.) contact pair and the number of cycles to third miss of the normally closed (N.C.) contact pair. This relay lifetime is the dependent variable in each regression analysis, and is denoted by Y throughout this discussion.

The independent variables are (transformations of) the I.M. or C.R. measurements (depending on the block of data being analyzed). In each block, the notation X_i, $i=1, \ldots, 18$ is used to denote the (I.M. or C.R.) measurements, X_1 being the initial measurement and $X_2, X_3, \ldots$ being succeeding measurements. The X_i's denote the measurements taken on the particular contact pair (N.O. or N.C.) which had the minimum number of cycles to third miss. Of course, for each relay, the variables X_i are defined only for those values of i indexing measurements taken before the end of relay lifetime. Hence, if the readings taken on a relay are $X_1, X_2, \ldots, X_k$ for some k, $1 \leq k \leq 18$, then the data from that relay can be used to fit any regression equation with independent variables $X_1, \ldots, X_j$ if $j \leq k$. However, if $j > k$, then the data from that relay cannot be used to fit a regression equation with independent variables $X_1, \ldots, X_j$.

Twenty different forms of regression models were investigated in this study. These were derived by combining each of five (5) basic transformations of the X_i's with each of four (4) basic regression equations. Table 6.5.1.1.2 lists the 5 sets of transformations used. Except for Set No. 1 (the identity transformation), the transformations are defined only for $i \geq 2$, since, for example, "change from the previous measurement" has no

TABLE 6.5.1.1.1 INDEX OF DATA BLOCKS

BLOCK NO.	ACCELERATED(A) OR NORMAL(N)	RELAY TYPE	QUANTITY MEASURED	NO. OF RELAYS IN BLOCK	NO. OF REGRESSION MODELS INVESTIGATED
1	A	B	I.M.	50	164
2	A	B	C.R.	50	124
3	A	C	I.M.	50	268
4	A	C	C.R.	50	204
5	N	B	I.M.	10	80
6	N	B	C.R.	10	60
7	N	C	I.M.	10	44
8	N	C	C.R.	12*	44

*Only 11 relays were tested completely, and the 12th relay was damaged during test. However, one of the contact pairs had already failed before damage to the other contact pair occurred, so that enough data was available on the 12th relay according to the definition of relay life used.

TABLE 6.5.1.1.2 FIVE BASIC DATA TRANSFORMATIONS

SET NO.	TRANSFORMATION	INTERPRETATION
1	$U_i=X_i$, $i=1, \ldots, k$	actual measurement
2	$U_i=X_i-X_{i-1}$, $i=2, \ldots, k$	change from the previous measurement
3	$U_i=X_i-X_1$, $i=2, \ldots, k$	change from the initial measurement
4	$U_i = \frac{X_i-X_{i-1}}{X_{i-1}}$, $i=2, \ldots, k$	relative change from the previous measurement
5	$U_i = \frac{X_i-X_1}{X_1}$, $i=2, \ldots, k$	relative change from the initial measurement

TABLE 6.5.1.1.3 FOUR BASIC REGRESSION EQUATIONS

EQUATION NO.	TYPE OF MODEL	BASIC REGRESSION EQUATION
1	Linear	$Y = c_0+c_1U_1+c_2U_2 + \ldots + c_kU_k + \epsilon$
2	Quadratic	$Y = c_0+c_1U_1^2+c_2U_2^2 + \ldots + c_kU_k^2 + \epsilon$
3	Logarithmic	$Y = c_0+c_1 \log U_1+c_2\log U_2 + \ldots +c_k\log U_k+ \epsilon$
4	Exponential	$Y = \exp(c_0+c_1U_1+c_2U_2 + \ldots + c_kU_k + \epsilon)$

meaning for $i=1$ (the initial measurement). For purely notational convenience, U_1 is defined by $U_1=0$ in Set 2 through Set 5.

Table 6.5.1.1.3 lists the 4 basic regression equations that were investigated. In each equation, ϵ denotes a normally distributed random variable with mean 0 and unknown variance σ^2. Equations 1,2, 3 and 4 express relay lifetime Y as linear, quadratic, logarithmic and exponential functions of the U_i's respectively.

As an example of how the 20 basic regression models are generated, consider Transformation Set No. 4 and Regression Equation No. 3. The resulting model is

$$Y = c_0+c_2 \log\left(\frac{X_2-X_1}{X_1}\right)+ c_3 \log\left(\frac{X_3-X_2}{X_2}\right)+ \dots + c_k \log\left(\frac{X_k-X_{k-1}}{X_{k-1}}\right)+ \epsilon.$$

In each block of data, each of the 20 basic regression models was investigated using a range of different values of k. For example, consider the case of using the model generated by Transformation Set No. 1 and Regression Equation No. 1 to fit the data in Block No. 5(Type B relay, normal conditions, I.M. measurements). There were 10 relays in the block and, of course, all 10 relays had an initial I.M. measurement. So for $k=1$, the model is

$$Y = c_0 + c_1X_1 + \epsilon$$

and the model was fitted using 10 data points, each "point" being a relay lifetime and an initial I.M. measurement (Y_j,X_{1j}), $j=1, \dots, 10$. Similarly, since all 10 relays survived to the second I.M. measurement, 10 data points were used to fit the model $Y = c_0+c_1X_1+c_2X_2+\epsilon$. For $k=3$, there were 3 relays that failed before the third I.M. measurement. Hence, only data from the 7 surviving relays were used to fit the model $Y = c_0+c_1X_1+c_2X_2+c_3X_3+\epsilon$. There were no relay failures before the next I.M. measurement, so data from the same 7 relays were used to fit the model for $k=4$. However, for $k=5$, there were only 6 relays that had not failed before the fifth I.M. measurement. Since there are 6 parameters to estimate $(c_0,c_1,\dots,c_6)$ in the regression equation, and since there are only 6 data points available, the regression equation cannot be fitted, since the number of data points does not exceed the number of parameters to be estimated.

The above example illustrates what happens for each block of data and each type of regression model. As k increases, the number of data points, n, available for fitting the model decreases. Eventually, the number of "degrees of freedom", n-k-1, is no longer greater than 0 and larger values of k cannot be used in the model. The last column of Table 6.5.1.1.1 gives the total number of regression models investigated for each data block, counting the models generated by different values of k as "different" models.

The totality of regression models investigated in this study has been described in the above paragraphs. One important fact to note about the models is that the number of cycles at which I.M. and C.R. readings were taken influence the model in only an indirect way: they determine the number of readings X_1, X_2, ... taken on each relay durings its lifetime. The actual magnitudes of the number of cycles at which readings were taken are not used in any of the regression model calculations.

6.5.1.2 THE MULTIPLE REGRESSION COMPUTER PROGRAM

As seen from Table 6.5.1.1.1, a total of 988 different regressions were run during the study.* A general computer program was used to make all these analyses. First, a main program was written to sort out and transform the data points for fitting each possible model, as described in Section 6.5.1.1. Then standard subroutines from the IBM Scientific Subrouting Package were used to perform multiple regression on each set of transformed data. The programmed regression computations are described below.

In each analysis, the data consisted of n vectors of observations $(Z_i, V_{i1}, V_{i2}, \ldots, V_{ik})$, i=1, ..., n, and the model to be fitted was of the form

$$Z = c_0 + c_1 V_1 + c_2 V_2 + \ldots + c_k V_k + \epsilon,$$

where the V's are the appropriate functions of the U's, and Z=Y in Regression Equations 1,2 and 3, Z = logY in Equation 4.

The regression program used was a stepwise regression program, which allows the user the option of deleting from the model those variables which are in a certain sense least important. This option was never used for the reason that the independent variables are generated from measurements $X_1, X_2, \ldots, X_k$ taken sequentially in time. Hence, if, say, X_2 were eliminated from the model, one would throw away information already available (the observations X_{i2}, i=1, ..., n). So all variables were entered into each model, and the stepwise regression was equivalent to a simple multiple regression analysis. For this reason, the analysis is described below without

*Actually, a total of 1455 regressions were run, but 467 of the runs provided no additional information. This latter group of runs used different definitions of relay life (e.g., number of cycles to third miss of the N.O. contact pair). These runs were discontinued after it was decided to restrict the analysis to a single definition of relay life.

discussing the criteria for the stepwise entering of variables.

The first subroutine computes sample means, standard deviations, and correlation coefficients. The sample means are given by

$$\bar{Z} = \frac{\sum_{i=1}^{n} Z_i}{n} \text{ and } \bar{V}_j = \frac{\sum_{i=1}^{n} V_{ij}}{n}, \ j=1, \ldots, k.$$

Then the following are computed:

$$S_{j\ell} = \sum_{i=1}^{n} (V_{ij}-T_j)(V_{i\ell}-T_\ell) - \frac{\sum_{i=1}^{n} (V_{ij}-T_j) \cdot \sum_{i=1}^{n} (V_{i\ell}-T_\ell)}{n}$$

where $j = 1,2,\ldots,k$; $\ell = 1,2,\ldots,k$; and $T_j = \frac{\sum_{i=1}^{k} V_{ij}}{k}$.

The sample correlation coefficients are given by

$$r_{j\ell} = \frac{S_{j\ell}}{\sqrt{S_{jj}}\sqrt{S_{\ell\ell}}}, \text{ where } j=1, \ldots, k; \ \ell=1, \ldots, k,$$

and sample standard deviations are given by

$$s_j = \frac{\sqrt{S_{jj}}}{\sqrt{n-1}}, \text{ where } j=1, \ldots, k.$$

Also, the quantities s_Z and r_{jZ}, $j=1, \ldots, k$, are computed, where s_Z is the sample standard deviation computed from the Z_i's, and r_{jZ} is the sample correlation coefficient of the j^{th} independent variable V_j with the dependent variable Z. The computation of these two quantities follows in obvious analogy from the formulas given above.

The next subroutine of the program computes the inverse of the correlation matrix

$$R = (r_{i\ell}), \ i=1, \ldots, k; \ \ell=1, \ldots, k.$$

The $i\ell$- element of the resulting matrix R^{-1} is denoted by $r^{-1}_{i\ell}$.

The main subroutine now computes all the statistics of interest. First, "beta weights" are calculated as follows:

$$\beta_j = \sum_{\ell=1}^{k} r_{\ell Z} \cdot r_{\ell j}^{-1}, \; j=1, \ldots., k.$$

Then, the regression coefficients are calculated:

$$c_j = \beta_j \cdot \frac{s_Z}{s_j}, \quad j=1, \ldots., k.$$

The intercept is found by the following equation:

$$c_0 = \bar{Z} - \sum_{j=1}^{k} c_j \bar{V}_j$$

The coefficient of determination is:

$$R^2 = \sum_{j=1}^{k} \beta_j r_{jZ} \, ,$$

and the multiple correlation coefficient $R(= \sqrt{R^2})$ is computed and adjusted for degrees of freedom by

$$R' = \sqrt{1-(1-R^2)(n-1)/(n-k)}$$

The sum of squares attributable to the regression is found by:

$$SSAR = R^2 \cdot \sum_{i=1}^{n} (Z_i - \bar{Z})^2,$$

and the sum of squares of deviations from the regression is given by:

$$SSDR = \sum_{i=1}^{n} (Z_i - \bar{Z})^2 - SSAR.$$

Then the F-value for analysis of variance is given by:

$$F_{OBS.} = \frac{SSAR/k}{SSDR/(n-k-1)}$$

The standard error of the estimated Z is obtained by

$$S = \sqrt{\frac{SSDR}{n-k-1}}$$

and adjusted by

$$S' = S\sqrt{(n-1)/(n-k)} .$$

Standard deviations of the regression coefficients are given by:

$$S_{c_j} = \sqrt{\frac{r_{jj}^{-1}}{\sum_{i=1}^{n} (V_{ij} - \bar{V}_j)^2} \cdot S^2} , \quad j=1, \ldots, k$$

Finally, the program computes t-values

$$t_j = \frac{c_j}{S_{c_j}} , \quad j=1, \ldots, k.$$

This completes the description of the output from the multiple regression program. The theoretical justification for these calculations follows from least squares theory. A good reference for the theory, including interpretations for all the statistics generated and examples, is Linear Statistical Inference and Its Applications, by C. R. Rao, John Wiley and Sons, Inc., New York, 1965, pp. 220-242.

6.5.1.3 CRITERIA FOR SELECTION OF THE "BEST" MODELS

For each of the 988 regression models investigated, all the statistics described above were generated. This section discusses the criteria used to compare the outputs and to select a "best" model for each of the 8 blocks of data analyzed.

In investigating the results of the regressions, there were two basic problems to keep in mind:

1. There may be no relationship at all between relay life and I.M. or C.R. measurements.

2. Even if there is a relationship, the true model may not be one of the ones investigated.

Because of 1. above, a cautious approach was taken in the analyses. It was assumed that there was no relationship between relay life and I.M. or C.R. measurement unless there was (statistically speaking) strong evidence of a relationship. As for problem 2. above, a conscious effort was made to select a wide and representative choice of models for investigation. The 5 different types of independent variables and 4 types of models (linear, quadratic, logarithmic, and exponential) were selected to cover a wide variety of possibilities, and at the same time to make the number of regressions investigated feasible (i.e., under 1000 in this study). Also, it was felt that even if the true model could not be uncovered, then one of the investigated models should be close enough to the true model for practical purposes.

In accordance with the above considerations, two statistics were selected as the basic measures for comparing models: $F_{OBS.}$ and R'. The F-statistic is used to test the null hypothesis that there is no relationship between relay life and the independent variable (I.M. or C.R.) against the alternative hypothesis that the model fits. For an α-level test, the null hypothesis is rejected if $F_{OBS.}$ exceeds the $(1-\alpha)$ point of the F-distribution with k and n-k-1 degrees of freedom. So for the data to show that a given model is valid, the value of the F-statistic should be high. In this study a minimum criterion was established for a model to be accepted: $F_{OBS.}$ must exceed the 90th percentage point of the F-distribution with k and n-k-1 degrees of freedom.

The second important measure for comparing models is R', the multiple correlation coefficient adjusted for degrees of freedom. R', a measure of how well the data fits the computed regression line, takes on values between 0 and 1, with large values demonstrating a good fit. The adjustment for degrees of freedom makes the values of R' for different models directly comparable. High values of R' are desirable for the models selected, but no rigid minimum standard was established as in the case of the F-statistic.

Consideration of $F_{OBS.}$ and R' alone lead to selection of the "best" models in most cases. In general, the model with the highest value of $F_{OBS.}$ was selected. However, in cases where two or more models yielded very high values of $F_{OBS.}$, the model with the highest R' was selected.

As indicated above, the selection of the best model for each block was a flexible, rather than rigid, procedure. Some other factors were considered besides the values of $F_{OBS.}$ and R'. One factor was that when two models were about equally "good," it was desirable to select the "simplest" model (e.g., to choose Transformation Set No. 1 over the four others). Also, from a practical point of view, models with the smallest values of k are most desirable. (A model with k=1 is ideal, since one could take an initial I.M. or C.R. reading on a relay and predict relay life without any further testing.) Hence, other things being about equal among competing models, the one with the smallest k was selected.

6.5.1.4 RESULTS OF THE ANALYSES

Table 6.5.1.4.1 gives a summary of some important quantities relating to the "best" models selected for each block according to the criteria in Section 6.5.1.3. The columns "Set No." and "Equation No." identifies the form of the

TABLE 6.5.1.4.1 SUMMARY OF MEASURES FOR THE FITTED MODELS

BLOCK NO.	ACCELERATED(A) OR NORMAL(N)	RELAY TYPE	QUANTITY MEASURED	SET NO.	EQUATION NO.	NO. OF INDEP. VARIABLES K	NO. OF DATA POINTS n	R'	$F_{OBS.}$	SIGNIFICANCE LEVEL α
1	A	B	I.M.	1	4	6	18	.6115	2.3154	.10
2	A	B	C.R.	1	4	4	35	.7989	15.231	< .0005
3	A	C	I.M.	1	4	4	34	.4165	2.3991	.08
4	A	C	C.R.	1	4	3	43	.4066	3.3542	.03
5	N	B	I.M.	3	2	4	6	.9501	6.1717	.34
6	N	B	C.R.	4	4	2	6	.8927	7.7329	.07
7	N	C	I.M.	4	3	2	5	.7588	2.1427	.36
8	N	C	C.R.	-	-	-	-	---	---	--

selected regression model (as coded in Tables 6.5.1.1.2 and 6.5.1.1.3). The columns identifying k,n,R′ and $F_{OBS.}$ for the selected models are self-explanatory. The last column, "significance level α," gives the level of the F-test which $F_{OBS.}$ is the critical value. The values of α were obtained by using a table of percentage points of the F-distribution with k and n-k-1 degrees of freedom.

The results from the accelerated tests (Blocks 1 through 4) were the most satisfactory, undoubtedly because there was considerably more data available (50 relays/block) in the accelerated tests than in the tests at normal conditions (10 relays/block). In analyzing the accelerated data, it was first noted in using each basic regression equation on each block of data, that nearly the same maximum values of R′ and $F_{OBS.}$ could be achieved no matter which of the 5 data transformation sets was used. (This pattern of regularity did not appear for the tests at normal conditions.) So in each of Blocks 1, 2,3 and 4, the search for a "best" model was restricted to models using Data Transformation No. 1. Within each block, the best model turned out to be one of the models using regression equation No. 4.

All the selected models in Blocks 1 through 4 have an acceptably high value of $F_{OBS.}$ (i.e., with significance level $\alpha \leq .10$ in each case). As for the values of R′, they seem acceptably high in the models for Blocks 1 and 2 (R′ = .62 and R′ = .80, respectively). The values of R′ in the models for Blocks 3 and 4 are rather low, but this negative factor is convincingly outweighed by the high values of $F_{OBS.}$. So an important conclusion of the statistical analysis in this study is the following:

For all the relays tested at accelerated conditions, the relationship between relay life Y and I.M. or C.R. measurements (denoted in either case by X_j, j=1, ..., k) can be well described by models of the form

$$Y = \exp(c_0+c_1X_1+c_2X_2 + \dots + c_kX_k + \epsilon).$$

For the relays tested at normal conditions, there is no uniformity of results, as seen in Blocks 5,6 and 7 of Table 6.5.1.4.1. In fact, the criteria had to be relaxed somewhat in order to designate "best" models for Blocks 5 and 7. For Block 8, none of the 44 models investigated yield a value of $F_{OBS.}$ that could result in the rejection of the null hypothesis of no relationship at even the $\alpha = .50$ level. So for Block 8, no model was selected. As was mentioned above, the probable cause for the poor results in Blocks 5 through 8 was the small sample size.

Tables 6.5.1.4.2 through 6.5.1.4.8 give the following additional information for each of the best models selected for Blocks 1 through 7:

- The multiple correlation coefficient.
- The multiple correlation coefficient adjusted for degrees of freedom (R′).
- The standard error of the estimate.

TABLE 6.5.1.4.2

Block No.	1
Test Conditions	Accelerated
Relay Type	B
Independent Variables, X_j	I.M. Products
Number of Measurements, k	6
Number of Data Points, n	18

Multiple Correlation Coefficient	.74706
Adjusted for Degrees of Freedom	.61153
Standard Error of the Estimate	.45266
Adjusted for Degrees of Freedom	.53877
F-Ratio for Sum of Squares Due to Regression	2.3154

Regression Equation:

$$Y = \exp(10.1339 - 1.6114X_1 + 2.9140X_2 - 9.3429X_3 - 4.1576X_4 + 8.1096X_5 + 4.7862X_6 + \epsilon).$$

TABLE 6.5.1.4.3

Block No.	2
Test Conditions	Accelerated
Relay Type	B
Independent Variables, X_j	C.R. Measurements
Number of Measurements, k	4
Number of Data Points, n	15

Multiple Correlation Coefficient	.81856
Adjusted for Degrees of Freedom	.79882
Standard Error of the Estimate	1.25876
Adjusted for Degrees of Freedom	1.31826
F-Ratio for Sum of Squares Due to Regression	15.2305

Regression Equation:

$$Y = \exp(8.33180 - .00509X_1 + .00396X_2 + .00523X_3 + .01481X_4 + \epsilon).$$

TABLE 6.5.1.4.4

Block No.	3
Test Conditions	Accelerated
Relay Type	C
Independent Variables, X_j	I.M. Products
Number of Measurements, k	4
Number of Data Points, n	34

Multiple Correlation Coefficient	.49863
Adjusted for Degrees of Freedom	.41653
Standard Error of the Estimate	1.0172
Adjusted for Degrees of Freedom	1.0669
F-Ratio for Sum of Squares Due to Regression	2.3991

Regression Equation:

$$Y = \exp(8.0595 - 7.7088X_1 + 3.0430X_2 - 1.8549X_3 + 6.5706X_4 + \epsilon).$$

TABLE 6.5.1.4.5

Block No.	4
Test Conditions	Accelerated
Relay Type	C
Independent Variables, X_j	C.R. Measurements
Number of Measurements, k	3
Number of Data Points, n	43

Multiple Correlation Coefficient	.45287
Adjusted for Degrees of Freedom	.40663
Standard Error of the Estimate	.80665
Adjusted for Degrees of Freedom	.82657
F-Ratio for Sum of Squares Due to Regression	3.3542

Regression Equation:

$$Y = \exp(7.20634 - .01335X_1 - .04453X_2 - .02241X_3 + \epsilon).$$

TABLE 6.5.1.4.6

Block No.	5
Test Conditions	Normal
Relay Type	B
Independent Variables, X_j	I.M. Products
Number of Measurements, k	5
Number of Data Points, n	6

Multiple Correlation Coefficient	.98034
Adjusted for Degrees of Freedom	.95009
Standard Error of the Estimate	2.8328×10^5
Adjusted for Degrees of Freedom	4.4791×10^5
F-Ratio for Sum of Squares Due to Regression	6.1717

Regression Equation:

$$Y = 2.7049 \times 10^6 + 1.7707 \times 10^5 x(X_2^2 - X_1^2) + 3.3586 \times 10^6 x(X_3^2 - X_1^2) + 1.0509 \times 10^7 x(X_4^2 - X_1^2) - 1.2489 \times 10^7 x(X_5^2 - X_1^2) + \epsilon.$$

TABLE 6.5.1.4.7

Block No.	6
Test Conditions	Normal
Relay Type	B
Independent Variables, X_j	C.R. Measurements
Number of Measurements, k	3
Number of Data Points, n	6

Multiple Correlation Coefficient	.91517
Adjusted for Degrees of Freedom	.89271
Standard Error of the Estimate	.32885
Adjusted for Degrees of Freedom	.36765
F-Ratio for Sum of Squares Due to Regression	7.7329

Regression Equation:

$$Y = \exp\left(15.5376 - 4.15998\left(\frac{X_2 - X_1}{X_1}\right) - 4.01936\left(\frac{X_3 - X_2}{X_2}\right) + \epsilon\right).$$

TABLE 6.5.1.4.8

Block No.	7
Test Conditions	Normal
Relay Type	C
Independent Variables, X_j	I.M. Products
Number of Measurements, k	3
Number of Data Points, n	5

Multiple Correlation Coefficient	.8257
Adjusted for Degrees of Freedom	.7588
Standard Error of the Estimate	1.9484×10^5
Adjusted for Degrees of Freedom	2.2499×10^5
F-Ratio for Sum of Squares Due to Regression	2.1427

Regression Equation:

$$Y = 4.9691 \times 10^5 - 8.1201 \times 10^6 \times \log\left(\frac{X_2 - X_1}{X_1}\right)$$

$$+ 9.0437 \times 10^6 \times \log\left(\frac{X_3 - X_2}{X_2}\right) + \epsilon.$$

- The standard error of the estimate adjusted for degrees of freedom.

- The F-Ratio for the sum of squares due to regression ($F_{OBS.}$).

- The fitted regression equation.

6.5.1.5 RESULTS OF SOME ADDITIONAL ANALYSES

The main result of Section 6.5.1.4 is that, for the accelerated tests, relay life Y can be determined by models of the form

$$Y = \exp(c_0+c_1X_1 + ... + c_kX_k + \epsilon). \qquad (1)$$

where $\{X_1, ..., X_k\}$ are successive I.M. or C.R. measurements. A natural question to investigate is whether the model

$$Y = \exp(c_0+c_1X_1+c_kX_k+\epsilon). \qquad (2)$$

is as good or better for predicting relay life. If so, then it would only be necessary to take an initial reading X_1 and a second reading X_k (at the number of cycles indexed by k), and omit the "in-between" readings. This procedure would, of course, be quite desirable from a practical point of view.

For each of Blocks 1 through 4, the regression program was run for the model of form (2) above, where the values of k used are those of the previously fitted models (Table 6.5.1.4.1).

Tables 6.5.1.5.1 and 6.5.1.5.2 give the results of the analyses of the new models for Blocks 1 and 3 (I.M. measurements on Relay Types B and C, respectively). Both models compare favorably with the selected models of the previous section. For the Block 1 data, the previous fitted model yielded a value of $F_{OBS.}$ of 2.32 with significance level $\alpha = .10$, while the new model had $F_{OBS.} = 3.49$, with significance level $\alpha = .06$. Thus, the evidence that the new model explains the true relationship between relay life and I.M. measurements is stronger than the corresponding evidence for the previous model. However, the multiple correlation coefficient adjusted for degrees of freedom, R', is only .5244, somewhat less than the R' of .6115 for the previous model.

For the Block 3 data, the new model yields an $F_{OBS.}$ with significance level .04, which is better than the .08 level of the previous fitted model. In addition, the R' for the new model is .4551, higher than the R' of .4165 for the previous model. Hence, for the Type C relay, the model that uses only the initial and sixth I.M. measurements is a better predictor of relay life than the model that uses all 6 measurements.

TABLE 6.5.1.5.1

Block No.	1
Test Conditions	Accelerated
Relay Type	B
Independent Variables, X_j	I.M. Products
Number of Measurements	2
Number of Data Points, n	18

Multiple Correlation Coefficient	.56363
Adjusted for Degrees of Freedom	.52443
Standard Error of the Estimate	.48167
Adjusted for Degrees of Freedom	.49650
F-Ratio for Sum of Squares Due to Regression	3.4919

Regression Equation:

$$Y = \exp(12.0714 - 4.4760X_1 + 4.3881X_6 + \epsilon).$$

TABLE 6.5.1.5.2

Block No.	3
Test Conditions	Accelerated
Relay Type	C
Independent Variables, X_j	I.M. Products
Number of Measurements	2
Number of Data Points, n	34

Multiple Correlation Coefficient	.48074
Adjusted for Degrees of Freedom	.45507
Standard Error of the Estimate	.99522
Adjusted for Degrees of Freedom	1.0106
F-Ratio for Sum of Squares Due to Regression	4.6591

Regression Equation:

$$Y = \exp(8.1286 - 7.6816X_1 + 7.7040X_4 + \epsilon).$$

The conclusion from the above discussion is that for relays tested at accelerated conditions, the model

$$Y = \exp(c_0+c_1X_1+c_kX_k+\epsilon)$$

using only the first and last I.M. measurements is as good a predictor of relay life as is the model using all k of the I.M. measurements.

For the models using C.R. measurements, a conclusion similar to the above could not be made. The new model for the Block 2 data does as well as the previous model for relay life. But the new model for the Block 4 data produces quite inadequate results: the value of F_{OBS} is not significant even at the .50 level, and the value of R is a very low .1511. So for Block 4, the previous model using 6 C.R. measurements is better for predicting relay life. Even if the model using only an initial and final C.R. measurement had produced good results in Block 4 as well as Block 2, it would have been difficult to draw a conclusion about the effect of not taking in-between readings. The reason for this is that for the data available, the in-between readings had, in fact, been taken. Since C.R. readings degrade relay life (as shown in Section 3.3), the in-between readings, whether used in the model or not, affect the data. The only way to see the true effect of using the new type of model for C.R. measurements is to run a new experiment taking only an initial measurement and one later measurement.

6.5.2 GOODNESS-OF-FIT TESTS

This section discusses an attempt that was made to fit failure distributions to each of the four blocks of relays tested under accelerated conditions. For each of the four blocks of data, parameters were estimated for each of 3 types of two-parameter failure distributions: Weibull, Lognormal, and Gamma. Chi-square tests were taken to test the goodness-of-fit of each of the estimated distributions. No attempt was made to fit failure distributions to the four blocks of relays tested at normal conditions, because a sample size of 10 is not adequate for taking a valid Chi-square test (there are not enough degrees of freedom). This does not mean that it is impossible to fit failure distributions with only 10 observations. For appropriate fitting methods, the reader is referred to Accelerated Reliability Testing for Non-electronic Parts, by R. E. Schafer and W. Yurkowsky, Technical Report No. RADC-TR-66-425, Sept., 1966.

In each of Blocks 1 through 4, the observed lifetimes of the 50 relays are denoted by $\{Y_i; i=1,\ldots,50\}$. Here, as throughout this report, the Y's are defined as the minimum of the number of cycles to third miss of the N.O. contact pair and the number of cycles to third miss of the N.C. contact pair.

Table 6.5.2.1 lists the 3 families of distributions used in attempting to fit relay failure data, and indicates the methods used to estimate parameters. The 3 distribution types were selected because they are well-known, tractable, and concentrate all of the mass on non-negative values. (This last property is obviously required of lifetime distributions.)

TABLE 6.5.2.1 DISTRIBUTIONS FOR FITTING ACCELERATED TEST DATA

Distribution	Parameters		Definition	Method of Estimating Parameters
Weibull	b	c	Density function* is $w(y;b,c) = \left(\frac{c}{b}\right)\left(\frac{y}{b}\right)^{c-1} \exp\{-\left(\frac{y}{b}\right)^{c}\}$	Maximum Likelihood
Log-normal	μ	σ^2	If $\log Y \sim$ Normal (μ,σ^2), then $Y \sim$ Lognormal (μ,σ^2)	Matching Moments after transformation to log Y_i
Gamma	α	λ	Density function* is $g(y;\alpha,\lambda) = \frac{\alpha^{\lambda}}{\Gamma(\lambda)} y^{\lambda-1} \exp\{-\alpha x\}$	Matching Moments

*The formula defines the density function for non-negative values of the argument y. For negative y, the density function equals 0.

The details of estimating the parameters b and c of the Weibull distribution by maximum likelihood are given in "Inferences on the Parameters of the Weibull Distribution," by Thoman, Bain and Antle, Technometrics, Vol. 11, No. 3, August 1969, pp. 445-460. The Lognormal parameters, μ and σ^2, were estimated by the sample mean and sample variance, respectively, of the quantities $\{\log Y_i, i=1,\ldots,50\}$. This procedure makes sense, since the $\log Y_i$ are presumed to be normally distributed, by definition. For estimating the Gamma parameters, the method of matching moments was used directly: the sample mean, $\hat{\mu}$, and the sample variance, $\hat{\sigma}^2$, of the $\{Y_i\}$ are equated to the distribution mean, λ/α, and variance, λ/α^2, respectively. The solution of the two equations yields the estimates

$$\hat{\alpha} = \hat{\mu}/\hat{\sigma}^2 \text{ and } \hat{\lambda} = \hat{\alpha}\hat{\mu}.$$

For each of the 4 data blocks, parameters were estimated for each of the 3 families of distributions. Then in each of the 12 cases, a Chi-square test of goodness-of-fit was taken. In each case, the test was taken using 7 cells, each cell having the same expected number of observations (namely, 50/7). Since in each case two unknown parameters were estimated, the appropriate degrees of freedom for the Chi-square test was 4(=7-2-1) in each case.

Tables 6.5.2.2 through 6.5.2.4 give the estimated parameters and the results of the Chi-square tests for the 12 cases considered. The second to the last columns in each table give the values of the test statistic

$$\chi^2 = \sum_{j=1}^{7} \frac{(O_j - E_j)^2}{E_j} ,$$

where O_j and E_j denote the observed and expected number of observations, respectively, in the j^{th} cell. Then, using a table of percentage points of the Chi-square distribution with 4 degrees of freedom, the approximate significance level α is determined in each case. The significance level α refers to the test of the null hypothesis of a "good fit," and is defined here to mean the level of the test for which the computed χ^2 is the critical value. As can be seen in the last column of each table, the α's are all low. The interpretation of this is that in all 12 cases, the data does not fit the distribution, since the null hypothesis is rejected at any "reasonable" test level (e.g., α = .05).

The conclusion from the goodness-of-fit tests is that lifetimes of relays tested at accelerated test conditions apparently do not have distributions that can be approximated by the known families of distributions investigated. Since the 3 families investigated are sufficiently "flexible," it is likely that the actual relay lifetimes distributions are too irregular to be represented by any known parametric family.

TABLE 6.5.2.2 ESTIMATED WEIBULL PARAMETERS AND RESULTS OF CHI-SQUARE TESTS

Block No.	Test Conditions	Relay Type	Quantity Measured	$\hat{c}$	$\hat{b}$	χ^2	Significance Level α
1	A	B	I.M.	.46896	40149.	15.52	.001
2	A	B	C.R.	.40473	17966.	13.84	.005
3	A	C	I.M.	.67590	3150.6	41.56	< .0001
4	A	C	C.R.	.80501	2446.5	19.44	.0005

TABLE 6.5.2.3 ESTIMATED LOGNORMAL PARAMETERS AND RESULTS OF CHI-SQUARE TESTS

Block No.	Test Conditions	Relay Type	Quantity Measured	$\hat{\mu}$	$\hat{\sigma}$	χ^2	Significance Level α
1	A	B	I.M.	9.3472	2.5982	13.56	.005
2	A	B	C.R.	8.4313	2.7463	11.88	.01
3	A	C	I.M.	7.3828	1.2263	18.32	.001
4	A	C	C.R.	7.2408	1.1011	11.32	.01

TABLE 6.5.2.4 ESTIMATED GAMMA PARAMETERS AND RESULTS OF CHI-SQUARE TESTS

Block No.	Test Conditions	Relay Type	Quantity Measured	$\hat{\alpha}$	$\hat{\lambda}$	χ^2	Significance Level α
1	A	B	I.M.	8.289×10^{-6}	.64264	56.96	<.0001
2	A	B	C.R.	7.720×10^{-6}	.39938	62.28	<.0001
3	A	C	I.M.	4.492×10^{-5}	.20844	23.64	<.0001
4	A	C	C.R.	7.553×10^{-5}	.21925	70.96	<.0001

6.6 FAILED PART ANALYSIS

Each failed relay was removed from its can and inspected under a 12x binocular microscope to determine the failure modes and mechanisms. In some cases, to better evaluate the condition of the contacts, higher magnification was used.

The general failure modes observed were classified and defined as shown in Figure 6.6.1. Each was assigned a code number to make the data handling problem easier. The results of the inspection are shown in Figures 6.6.2 through 6.6.5.

CODE NO.	TERMINOLOGY
1.	Material transfer from the contacts to the blade.
2.	Material transfer from the blade to the contacts.
3.	Contacts welded to blade.
4.	Deposits of vaporized material on header in contact area.
5.	Contacts show evidence of misalignment.
6.	Very little contact wear.
7.	Actuator bead cracked.
8.	Movable contact has depression with raised perimeter formed by adjacent contact. Contact surface appears to have been molten.
9.	Stationary contact has depression formed by movable contact.

Figure 6.6.1 Failure Report: Code and Terminology

The equipment used for the Failure Part Analysis was a Binocular Microscope, Wild, H-187268, M5-47799.

CODE NO.	TERMINOLOGY	CONSTRICTION RESISTANCE		I.M. PRODUCTS	
		N.C.	N.O.	N.C.	N.O.
1	Material transfer from the contacts to the blade.	17	33	25	46
2	Material transfer from the blade to the contacts.	1	1	-	-
3	Contacts welded to blade.	-	2	-	-
4	Deposits of vaporized material on header in contact area.	23	42	24	41
5	Contacts show evidence of misalignment.	39	30	25	12
6	Very little contact wear.	36	17	21	7
7	Actuator bead cracked.	1	-	-	-
8	Movable contact has depression with raised perimeter formed by adjacent contact. Contact surface appears to have been molten.	10	31	15	18
9	Stationary contact has depression formed by movable contact.	-	-	-	-

NOTE: Fifty (50) relays with Constriction Resistance measurements.
Fifty (50) relays with I.M. Products measurements.

Figure 6.6.2 Failure Mode for Type B Relays
Accelerated Conditions

CODE NO.	TERMINOLOGY	CONSTRICTION RESISTANCE		I.M. PRODUCTS	
		N.C.	N.O.	N.C.	N.O.
1	Material transfer from the contacts to the blade.	9	10	10	10
2	Material transfer from the blade to the contacts.	0	1	0	0
3	Contacts welded to blade.	-	-	-	-
4	Deposits of vaporized material on header in contact area.	9	9	10	9
5	Contacts show evidence of misalignment.	4	5	4	4
6	Very little contact wear.	4	4	3	2
7	Actuator bead cracked.	-	-	-	-
8	Movable contact has depression with raised perimeter formed by adjacent contact. Contact surface appears to have been molten.	0	1	0	0
9	Stationary contact has depression formed by movable contact.	-	-	-	-

NOTE: Ten (10) relays with Constriction Resistance measurements.
Ten (10) relays with I.M. Products measurements.

Figure 6.6.3 Failure Modes for Type B Relays
Normal Conditions

CODE NO.	TERMINOLOGY	CONSTRICTION RESISTANCE		I.M. PRODUCTS	
		N.C.	N.O.	N.C.	N.O.
1	Material transfer from the contacts to the blade.	7	10	20	22
2	Material transfer from the blade to the contacts.	-	1	-	1
3	Contacts welded to blade.	-	-	-	-
4	Deposits of vaporized material on header in contact area.	19	23	15	12
5	Contacts show evidence of misalignment.	14	12	12	10
6	Very little contact wear.	45	39	33	31
7	Actuator bead cracked.	-	-	-	-
8	Movable contact has depression with raised perimeter formed by adjacent contact. Contact surface appears to have been molten.	1	-	-	-
9	Stationary contact has depression formed by movable contact.	1	-	4	7

NOTE: Fifty (50) relays with Constriction Resistance measurements.
Fifty (50) relays with I.M. Products measurements.

Figure 6.6.4 Failure Modes for Type C Relays
Accelerated Conditions

CODE NO.	TERMINOLOGY	CONSTRICTION RESISTANCE		I.M. PRODUCTS	
		N.C.	N.O.	N.C.	N.O.
1	Material transfer from the contacts to the blade.	8	10	10	10
2	Material transfer from the blade to the contacts.	0	0	0	0
3	Contacts welded to blade.	-	-	-	-
4	Deposits of vaporized material on header in contact area.	11	11	10	10
5	Contacts show evidence of misalignment.	4	0	2	2
6	Very little contact wear.	2	1	0	0
7	Actuator bead cracked.	-	-	-	-
8	Movable contact has depression with raised perimeter formed by adjacent contact. Contact surface appears to have been molten.	-	-	-	-
9	Stationary contact has depression formed by movable contact.	9	7	8	6

NOTE: Eleven (11) relays with Constriction Resistance measurements.
Ten (10) relays with I.M. Products measurements.

Figure 6.6.5 Failure Modes for Type C Relays
Normal Conditions.

6.7 RELAY TEST DATA

This section presents all the relay test data used as input to the regression analyses. With the data in this section and the description in Section 6.5, the reader should be able to reproduce all the results of the regression analyses presented in this report. The data is presented for 9 blocks of data:

1. Type B Relays, Accelerated Test Conditions with I.M. Products Measurements.

2. Type B Relays, Accelerated Test Conditions with C.R. Measurements.

3. Type C Relays, Accelerated Test Conditions with I.M. Products Measurements - Relays No. 1 through 15.

4. Type C Relays, Accelerated Test Conditions with I.M. Products Measurements - Relays No. 16 through 50.

5. Type C Relays, Accelerated Test Conditions with C.R. Measurements.

6. Type B Relays, Normal Test Conditions with I.M. Products Measurements.

7. Type B Relays, Normal Test Conditions with C.R. Measurements.

8. Type C Relays, Normal Test Conditions with I.M. Products Measurements.

9. Type C Relays, Normal Test Conditions with C.R. Measurements.

6.7 RELAY TEST DATA

This section presents all the relay test data used as input to the regression analyses. With the data in this section and the description in Section 6.5, the reader should be able to reproduce all the results of the regression analyses presented in this report. The data is presented for 9 blocks of data:

1. Type B Relays, Accelerated Test Conditions with I.M. Products Measurements.

2. Type B Relays, Accelerated Test Conditions with C.R. Measurements.

3. Type C Relays, Accelerated Test Conditions with I.M. Products Measurements - Relays No. 1 through 15.

4. Type C Relays, Accelerated Test Conditions with I.M. Products Measurements - Relays No. 16 through 50.

5. Type C Relays, Accelerated Test Conditions with C.R. Measurements.

6. Type B Relays, Normal Test Conditions with I.M. Products Measurements.

7. Type B Relays, Normal Test Conditions with C.R. Measurements.

8. Type C Relays, Normal Test Conditions with I.M. Products Measurements.

9. Type C Relays, Normal Test Conditions with C.R. Measurements.

6.7.1 TYPE B RELAYS, ACCELERATED TEST CONDITIONS WITH I.M. PRODUCTS MEASUREMENTS

The data for the 50 Type B relays that received I.M. products measurements under accelerated test conditions is given on the following 13 pages. Accelerated conditions refer to a 6 amp. contact load, 25°C temperature and a 60 hz. actuation rate. I.M. product measurements (in mv. units) are given for both the normally closed (N.C.) contacts and normally open (N.O.) contacts on each relay. The number of cycles at the first, second and third miss of each contact is also given. The number of cycles at which readings were taken are indexed as follows.

1.	75 cycles	10.	225,000 cycles
2.	500 cycles	11.	240,000 cycles
3.	750 cycles	12.	350,000 cycles
4.	13,400 cycles	13.	475,000 cycles
5.	17,600 cycles	14.	500,000 cycles
6.	105,000 cycles	15.	585,000 cycles
7.	153,000 cycles	16.	635,000 cycles
8.	180,000 cycles	17.	680,000 cycles
9.	210,000 cycles		

CYCLE NO.	N.C. CONTACT	N.O. CONTACT
INITIAL	2.09	2.18
1	2.07	2.16
2	2.08	2.28
3	2.09	2.26
4	2.10	2.28
5	2.12	2.30
6	2.12	2.28
7		2.30
8		2.23
9		2.28
10		2.33
11		2.30
12		
13		
14		
15		
16		
17		
CYCLES 1.	75890.	199321.
AT 2.	92078.	273909.
MISS 3.	135029.	295650.

CYCLE NO.	N.C. CONTACT	N.O. CONTACT
INITIAL	2.30	2.36
1	2.32	2.38
2	2.31	2.50
3	2.32	2.49
4	2.35	2.50
5	2.37	2.50
6	2.41	2.50
7	2.35	2.52
8	2.40	
9	2.32	
10	2.36	
11	2.35	
12	2.41	
13		
14		
15		
16		
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CYCLES 1.	451655.	173669.
AT 2.	451672.	173670.
MISS 3.	451673.	173712.

CYCLE NO.	N.C. CONTACT	N.O. CONTACT
INITIAL	2.12	2.31
1	2.08	2.24
2	2.09	2.30
3	2.08	2.28
4	2.18	2.30
5	2.19	2.35
6	2.22	2.34
7	2.12	2.35
8	2.22	2.38
9	2.13	2.32
10	2.20	
11	2.19	
12	2.21	
13	2.21	
14	2.21	
15	2.21	
16	2.21	
17	2.22	
CYCLES 1.	743165.	208003.
AT 2.	1294960.	211079.
MISS 3.	1314282.	211259.

CYCLE NO.	N.C. CONTACT	N.O. CONTACT
INITIAL	2.26	2.50
1	2.24	2.48
2	2.25	2.51
3	2.25	2.50
4	2.28	2.52
5	2.29	2.59
6	2.32	2.49
7	2.30	2.59
8	2.32	2.59
9		2.52
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CYCLES 1.	133743.	199301.
AT 2.	199230.	210040.
MISS 3.	199231.	210043.

CYCLE NO.	N.C. CONTACT	N.O. CONTACT
INITIAL	2.51	2.48
1	2.51	2.39
2	2.47	2.46
3	2.48	2.44
4	2.51	2.44
5		2.49
6		2.49
7		2.50
8		2.51
9		2.45
10		2.50
11		2.48
12		
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CYCLES 1.	67688.	199300.
AT 2.	67689.	199301.
MISS 3.	67690.	276200.

CYCLE NO.	N.C. CONTACT	N.O. CONTACT
INITIAL	2.42	2.20
1	2.42	2.22
2	2.42	2.28
3	2.47	2.26
4		2.31
5		2.26
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CYCLES 1.	108.	90452.
AT 2.	608.	90453.
MISS 3.	998.	90454.

CYCLE NO.	N.C. CONTACT	N.O. CONTACT
INITIAL	2.03	2.68
1	1.99	2.67
2	2.00	2.71
3	2.02	2.71
4	2.05	2.72
5	2.09	2.68
6	2.02	2.71
7	2.03	2.72
8	2.04	2.77
9	2.02	
10	2.02	
11	2.03	
12		
13		
14		
15		
16		
17		
CYCLES 1.	326979.	180039.
AT 2.	326980.	204312.
MISS 3.	326981.	204313.

CYCLE NO.	N.C. CONTACT	N.O. CONTACT
INITIAL	2.27	2.38
1	2.24	2.31
2	2.29	2.33
3	2.29	2.33
4	2.31	2.29
5	2.31	2.22
6	2.24	
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CYCLES 1.	148869.	32548.
AT 2.	148887.	32549.
MISS 3.	148888.	32550.

CYCLE NO.	N.C. CONTACT	N.O. CONTACT
INITIAL	2.40	2.37
1	2.40	2.32
2	2.44	2.35
3	2.43	2.33
4	2.41	2.32
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CYCLES 1.	49478.	59367.
AT 2.	49479.	59368.
MISS 3.	49480.	59369.

CYCLE NO.	N.C. CONTACT	N.O. CONTACT
INITIAL	2.20	2.56
1	2.18	2.58
2	2.21	2.58
3	2.22	2.58
4	2.24	2.46
5		2.59
6		
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CYCLES 1.	70858.	102171.
AT 2.	70859.	102172.
MISS 3.	70860.	102173.

CYCLE NO.	N.C. CONTACT	N.O. CONTACT
INITIAL	2.18	2.19
1	2.19	2.21
2	2.19	2.21
3	2.22	2.23
4		2.23
5		2.32
6		2.29
7		2.28
8		2.29
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CYCLES 1.	1022.	205903.
AT 2.	1643.	205920.
MISS 3.	3334.	205921.

CYCLE NO.	N.C. CONTACT	N.O. CONTACT
INITIAL	2.12	2.31
1	2.12	2.28
2	2.16	2.32
3	2.17	2.33
4	2.17	2.36
5	2.22	2.43
6	2.18	2.39
7	2.21	2.40
8	2.24	2.42
9	2.20	
10	2.20	
11	2.19	
12		
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14		
15		
16		
17		
CYCLES 1.	10512.	200826.
AT 2.	271740.	200827.
MISS 3.	327590.	200828.

CYCLE NO.		N.C. CONTACT	N.O. CONTACT
INITIAL		2.49	2.47
1		2.48	2.47
2		2.49	2.41
3			2.48
4			2.48
5			
6			
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CYCLES	1.	329.	74029.
AT	2.	330.	74030.
MISS	3.	331.	75302.

CYCLE NO.		N.C. CONTACT	N.O. CONTACT
INITIAL		2.37	2.19
1		2.37	2.14
2		2.38	2.11
3			2.19
4			2.21
5			2.29
6			2.22
7			2.22
8			2.25
9			2.22
10			2.25
11			2.25
12			2.22
13			
14			
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16			
17			
CYCLES	1.	249.	423522.
AT	2.	250.	423523.
MISS	3.	251.	423524.

CYCLE NO.		N.C. CONTACT	N.O. CONTACT
INITIAL		2.30	2.24
1		2.31	2.20
2		2.31	2.25
3		2.30	2.28
4			
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CYCLES	1.	1057.	6252.
AT	2.	1058.	6320.
MISS	3.	1059.	6321.

CYCLE NO.		N.C. CONTACT	N.O. CONTACT
INITIAL		2.28	1.99
1		2.29	2.01
2		2.29	1.99
3			2.00
4			2.01
5			2.07
6			2.03
7			2.01
8			1.98
9			
10			
11			
12			
13			
14			
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16			
17			
CYCLES	1.	140.	14231.
AT	2.	531.	200260.
MISS	3.	712.	200284.

CYCLE NO.		N.C. CONTACT	N.O. CONTACT
INITIAL		1.86	1.76
1		1.87	1.82
2			1.81
3			1.80
4			1.80
5			1.82
6			1.79
7			1.73
8			1.82
9			1.82
10			1.83
11			1.86
12			
13			
14			
15			
16			
17			
CYCLES	1.	234.	250651.
AT	2.	235.	253924.
MISS	3.	254.	253925.

CYCLE NO.		N.C. CONTACT	N.O. CONTACT
INITIAL		2.58	2.73
1		2.58	2.74
2		2.62	2.76
3		2.61	2.72
4		2.61	2.77
5			
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15			
16			
17			
CYCLES	1.	48562.	14080.
AT	2.	48563.	14231.
MISS	3.	48564.	14550.

CYCLE NO.		N.C. CONTACT	N.O. CONTACT
INITIAL		2.52	2.43
1		2.52	2.46
2		2.53	2.46
3		2.53	2.42
4		2.56	2.46
5		2.52	2.46
6		2.61	2.50
7		2.54	2.48
8		2.55	2.47
9		2.47	2.43
10		2.49	2.53
11		2.60	2.54
12			2.51
13			2.30
14			2.50
15			
16			
17			
CYCLES	1.	262068.	14231.
AT	2.	262069.	302989.
MISS	3.	262070.	514192.

CYCLE NO.		N.C. CONTACT	N.O. CONTACT
INITIAL		2.01	1.97
1		2.02	1.98
2		2.02	1.94
3		2.01	1.92
4		2.02	1.98
5		2.04	1.97
6		2.12	2.00
7		2.10	1.99
8		2.09	1.96
9		2.02	1.89
10		2.08	1.98
11		2.13	
12		2.08	
13		2.09	
14		2.10	
15		2.10	
16		2.10	
17		2.10	
CYCLES	1.	1089.	14231.
AT	2.	798262.	230868.
MISS	3.	1383527.	237416.

CYCLE NO.		N.C. CONTACT	N.O. CONTACT
INITIAL		2.16	2.30
1		2.12	2.27
2		2.15	2.30
3		2.18	2.29
4		2.19	2.31
5			2.31
6			2.34
7			2.32
8			2.33
9			
10			
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12			
13			
14			
15			
16			
17			
CYCLES	1.	6509.	193418.
AT	2.	12019.	197719.
MISS	3.	13910.	197720.

CYCLE NO.		N.C. CONTACT	N.O. CONTACT
INITIAL		2.42	2.36
1		2.41	2.37
2		2.39	2.42
3		2.40	2.43
4		2.41	2.41
5		2.42	2.45
6			2.47
7			
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13			
14			
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16			
17			
CYCLES	1.	98568.	119508.
AT	2.	98570.	119509.
MISS	3.	98590.	119510.

CYCLE NO.		N.C. CONTACT	N.O. CONTACT
INITIAL		2.28	2.67
1		2.30	2.68
2		2.31	2.70
3		2.32	2.71
4			
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16			
17			
CYCLES	1.	2648.	1249.
AT	2.	2649.	1250.
MISS	3.	2650.	1251.

CYCLE NO.		N.C. CONTACT	N.O. CONTACT
INITIAL		2.54	2.32
1		2.50	2.37
2		2.52	2.34
3		2.53	2.31
4		2.52	2.33
5		2.54	2.34
6		2.54	2.34
7		2.54	2.37
8		2.55	2.39
9		2.56	2.40
10		2.53	
11		2.61	
12			
13			
14			
15			
16			
17			
CYCLES	1.	254360.	214109.
AT	2.	254379.	214659.
MISS	3.	254380.	214660.

CYCLE NO.	N.C. CONTACT	N.O. CONTACT
INITIAL	2.05	2.16
1	2.07	2.12
2	2.06	2.14
3	2.08	2.14
4	2.05	2.16
5	2.07	
6	2.09	
7	2.12	
8	2.15	
9	2.16	
10	2.11	
11	2.08	
12	2.10	
13	2.11	
14	2.13	
15	2.12	
16	2.14	
17	2.15	
CYCLES 1.	948707.	52292.
AT 2.	948708.	68082.
MISS 3.	948709.	68083.

CYCLE NO.	N.C. CONTACT	N.O. CONTACT
INITIAL	2.21	1.99
1	2.19	2.01
2	2.18	2.02
3	2.15	2.04
4		2.03
5		2.05
6		2.06
7		2.09
8		2.11
9		2.12
10		
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14		
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17		
CYCLES 1.	318.	215878.
AT 2.	2610.	220329.
MISS 3.	2959.	230230.

CYCLE NO.	N.C. CONTACT	N.O. CONTACT
INITIAL	2.37	2.61
1	2.35	2.61
2	2.37	2.60
3	2.38	2.62
4	2.38	2.63
5	2.39	2.65
6	2.40	2.68
7		2.66
8		2.69
9		2.70
10		
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12		
13		
14		
15		
16		
17		
CYCLES 1.	6418.	64808.
AT 2.	11013.	64809.
MISS 3.	113559.	210820.

CYCLE NO.	N.C. CONTACT	N.O. CONTACT
INITIAL	2.48	2.49
1	2.45	2.50
2	2.46	2.52
3	2.47	2.53
4		2.51
5		2.52
6		2.53
7		2.53
8		2.54
9		2.56
10		2.55
11		2.57
12		2.58
13		2.60
14		
15		
16		
17		
CYCLES 1.	1248.	102470.
AT 2.	1249.	273369.
MISS 3.	1250.	476162.

CYCLE NO.		N.C. CONTACT	N.O. CONTACT
INITIAL		2.07	2.23
1		2.05	2.24
2		2.06	2.21
3		2.08	2.23
4		2.09	2.25
5		2.11	2.26
6		2.08	2.24
7		2.10	2.27
8		2.11	2.28
9		2.12	2.31
10		2.14	2.30
11		2.15	2.30
12			
13			
14			
15			
16			
17			
CYCLES	1.	133190.	212301.
AT	2.	298032.	297422.
MISS	3.	298051.	297423.

CYCLE NO.		N.C. CONTACT	N.O. CONTACT
INITIAL		2.30	2.64
1		2.29	2.65
2		2.30	2.67
3		2.33	2.64
4			2.65
5			
6			
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13			
14			
15			
16			
17			
CYCLES	1.	4079.	55118.
AT	2.	4080	55119
MISS	3.	4105.	55569.

CYCLE NO.		N.C. CONTACT	N.O. CONTACT
INITIAL		2.30	2.32
1		2.25	2.24
2		2.18	2.41
3		2.23	2.28
4			2.49
5			2.49
6			2.31
7			2.56
8			2.47
9			2.55
10			2.53
11			2.51
12			
13			
14			
15			
16			
17			
CYCLES	1.	520.	435898.
AT	2.	828.	443578.
MISS	3.	1151.	443660.

CYCLE NO.		N.C. CONTACT	N.O. CONTACT
INITIAL		2.78	2.36
1		2.79	2.25
2		2.78	2.24
3		2.74	2.23
4		2.82	2.27
5		2.82	
6		2.81	
7		2.81	
8		2.78	
9		2.79	
10		2.79	
11		2.77	
12		2.72	
13		2.80	
14		2.76	
15		2.76	
16		2.78	
17		2.76	
CYCLES	1.	426170.	62900.
AT	2.	1135528.	62901.
MISS	3.	1135535.	62902.

CYCLE NO.		N.C. CONTACT	N.O. CONTACT
INITIAL		2.33	2.08
1		2.31	2.06
2		2.31	2.07
3		2.31	2.03
4			2.03
5			2.11
6			2.13
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14			
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16			
17			
CYCLES	1.	970.	59150.
AT	2.	971.	108159.
MISS	3.	972.	108160.

CYCLE NO.		N.C. CONTACT	N.O. CONTACT
INITIAL		2.55	2.40
1		2.50	2.32
2			2.32
3			2.33
4			2.34
5			2.41
6			2.42
7			2.45
8			2.47
9			2.46
10			2.47
11			2.43
12			
13			
14			
15			
16			
17			
CYCLES	1.	238.	54660.
AT	2.	239.	323997.
MISS	3.	240.	323998.

CYCLE NO.		N.C. CONTACT	N.O. CONTACT
INITIAL		2.22	2.28
1		2.18	2.27
2		2.17	2.27
3			2.21
4			2.22
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16			
17			
CYCLES	1.	728.	54500.
AT	2.	729.	60493.
MISS	3.	730.	60512.

CYCLE NO.		N.C. CONTACT	N.O. CONTACT
INITIAL		2.48	2.23
1		2.42	2.18
2			2.19
3			2.19
4			2.22
5			2.27
6			2.24
7			2.29
8			2.28
9			2.30
10			2.31
11			2.34
12			
13			
14			
15			
16			
17			
CYCLES	1.	64.	238054.
AT	2.	184.	257100.
MISS	3.	185.	257741.

CYCLE NO.		N.C. CONTACT	N.O. CONTACT
INITIAL		2.31	2.28
1		2.28	2.32
2		2.30	2.38
3		2.29	2.33
4		2.32	2.40
5		2.33	2.39
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15			
16			
17			
CYCLES	1.	85118.	85118.
AT	2.	85119.	85119.
MISS	3.	85120.	85120.

CYCLE NO.		N.C. CONTACT	N.O. CONTACT
INITIAL		2.28	2.65
1		2.29	2.65
2		2.31	2.64
3		2.30	2.68
4		2.34	2.70
5		2.34	2.72
6		2.35	2.74
7		2.36	2.74
8		2.35	2.74
9			
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12			
13			
14			
15			
16			
17			
CYCLES	1.	187556.	187556.
AT	2.	187557.	187557.
MISS	3.	187558.	187558.

CYCLE NO.		N.C. CONTACT	N.O. CONTACT
INITIAL		2.55	2.63
1		2.52	2.64
2			2.66
3			2.65
4			2.62
5			2.63
6			
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17			
CYCLES	1.	428.	85570.
AT	2.	429.	85774.
MISS	3.	430.	86520.

CYCLE NO.		N.C. CONTACT	N.O. CONTACT
INITIAL		2.20	2.26
1		2.13	2.21
2		2.15	2.21
3		2.16	2.24
4		2.16	2.23
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15			
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17			
CYCLES	1.	51808.	23488.
AT	2.	51809.	23489.
MISS	3.	51810.	23490.

CYCLE NO.		N.C. CONTACT	N.O. CONTACT
INITIAL		2.03	1.75
1		2.00	1.80
2		2.03	1.76
3		2.00	1.77
4			1.79
5			1.79
6			1.82
7			1.83
8			1.81
9			1.85
10			1.83
11			1.86
12			
13			
14			
15			
16			
17.			
CYCLES	1.	130.	271811.
AT	2.	780.	275659.
MISS	3.	801.	275678.

CYCLE NO.		N.C. CONTACT	N.O. CONTACT
INITIAL		2.42	2.39
1		2.40	2.43
2		2.43	2.35
3		2.40	2.41
4		2.42	2.41
5		2.46	2.45
6		2.46	2.43
7		2.49	2.46
8		2.49	2.49
9		2.49	2.48
10		2.45	2.48
11		2.48	
12		2.48	
13			
14			
15			
16			
17			
CYCLES	1.	363474.	235489.
AT	2.	363510.	235507.
MISS	3.	363920.	235506.

CYCLE NO.		N.C. CONTACT	N.O. CONTACT
INITIAL		2.18	2.21
1		2.16	2.21
2		2.22	2.21
3		2.18	2.23
4		2.20	2.27
5		2.21	
6		2.21	
7			
8			
9			
10			
11			
12			
13			
14			
15			
16			
17			
CYCLES	1.	11148.	63119.
AT	2.	11230.	63137.
MISS	3.	135608.	63138.

CYCLE NO.		N.C. CONTACT	N.O. CONTACT
INITIAL		2.44	1.84
1		2.43	1.92
2		2.48	1.92
3		2.45	1.95
4			1.93
5			1.97
6			1.97
7			1.95
8			1.97
9			
10			
11			
12			
13			
14			
15			
16			
17			
CYCLES	1.	4950.	158123.
AT	2.	5395.	207628.
MISS	3.	5798.	208235.

CYCLE NO.	N.C. CONTACT	N.O. CONTACT
INITIAL	2.40	2.04
1	2.37	2.15
2	2.42	2.08
3		2.08
4		2.09
5		2.09
6		2.09
7		2.11
8		2.12
9		
10		
11		
12		
13		
14		
15		
16		
17		
CYCLES 1.	701.	201428.
AT 2.	702.	201429.
MISS 3.	703.	201430.

CYCLE NO.	N.C. CONTACT	N.O. CONTACT
INITIAL	2.12	2.27
1	2.18	2.22
2		2.25
3		2.24
4		2.20
5		2.30
6		2.32
7		2.32
8		2.30
9		2.27
10		
11		
12		
13		
14		
15		
16		
17		
CYCLES 1.	49.	219231.
AT 2.	243.	219893.
MISS 3.	244.	221050.

CYCLE NO.	N.C. CONTACT	N.O. CONTACT
INITIAL	2.50	2.35
1	2.48	2.32
2	2.48	2.35
3	2.51	2.35
4		2.33
5		2.37
6		2.37
7		2.32
8		2.33
9		2.28
10		2.32
11		2.31
12		
13		
14		
15		
16		
17		
CYCLES 1.	1716.	281987.
AT 2.	1717.	281988.
MISS 3.	1718.	282004.

CYCLE NO.	N.C. CONTACT	N.O. CONTACT
INITIAL	2.52	2.19
1	2.49	2.25
2	2.49	2.25
3	2.51	2.26
4	2.48	2.31
5	2.61	2.34
6	2.57	2.32
7	2.61	2.34
8	2.61	2.32
9	2.63	2.32
10	2.61	2.32
11	2.61	2.30
12	2.59	
13	2.59	
14	2.56	
15	2.59	
16	2.59	
17	2.59	
CYCLES 1.	587010.	261669.
AT 2.	787571.	284081.
MISS 3.	787572.	331493.

CYCLE NO.		N.C. CONTACT	N.O. CONTACT
INITIAL		2.58	2.43
1		2.59	2.40
2		2.58	2.42
3		2.61	2.43
4			2.43
5			2.51
6			2.50
7			2.52
8			2.49
9			2.48
10			2.50
11			2.45
12			
13			
14			
15			
16			
17			
CYCLES	1.	1004.	284976.
AT	2.	1005.	286103.
MISS	3.	1020.	325011.

CYCLE NO.		N.C. CONTACT	N.O. CONTACT
INITIAL		2.05	2.33
1		2.02	2.35
2		2.05	2.33
3		2.06	2.37
4		2.01	2.34
5		2.09	2.40
6		2.08	2.38
7		2.11	2.40
8		2.08	2.41
9		2.09	
10		2.05	
11			
12			
13			
14			
15			
16			
17			
CYCLES	1.	232834.	191125.
AT	2.	233080.	191305.
MISS	3.	233810.	191609.

6.7.2 TYPE B RELAYS, ACCELERATED TEST CONDITIONS WITH C.R. MEASUREMENTS

The data from the 50 relays which were tested at accelerated conditions with C.R. measurements is presented on the next 13 pages. The C.R. measurements are given in amps. The codes 1-17 refer to the same numbers of test cycles given in Subsection 6.7.1.

CYCLE NO.		N.C. CONTACT	N.O. CONTACT
INITIAL		7.6	8.8
1		79.0	79.8
2			22.2
3			84.0
4			11.8
5			142.0
6			
7			
8			
9			
10			
11			
12			
13			
14			
15			
16			
17			
CYCLES	1.	55.	99819.
AT	2.	221.	102720.
MISS	3.	454.	102721.

CYCLE NO.		N.C. CONTACT	N.O. CONTACT
INITIAL		6.8	4.8
1		134.0	231.0
2		83.8	81.8
3		53.8	34.0
4			37.2
5			57.3
6			260.0
7			150.0
8			181.0
9			177.0
10			180.0
11			188.0
12			
13			
14			
15			
16			
17			
CYCLES	1.	8000.	410353.
AT	2.	8429.	430180.
MISS	3.	9051.	430796.

CYCLE NO.		N.C. CONTACT	N.O. CONTACT
INITIAL		4.1	3.0
1		81.0	183.0
2		81.0	169.0
3		82.3	148.0
4		167.0	267.0
5		340.0	
6		340.0	
7		340.0	
8		340.0	
9			
10			
11			
12			
13			
14			
15			
16			
17			
CYCLES	1.	193980.	49910.
AT	2.	193981.	49911.
MISS	3.	193982.	49912.

CYCLE NO.		N.C. CONTACT	N.O. CONTACT
INITIAL		3.8	8.6
1		4.0	81.4
2		79.9	
3		63.7	
4			
5			
6			
7			
8			
9			
10			
11			
12			
13			
14			
15			
16			
17			
CYCLES	1.	1229.	381.
AT	2.	1230.	382.
MISS	3.	1231.	383.

CYCLE NO.		N.C. CONTACT	N.O. CONTACT
INITIAL		5.9	8.5
1		64.4	11.0
2		115.0	187.0
3		82.2	170.0
4		22.9	82.5
5		82.1	219.0
6		227.0	263.0
7		212.0	330.0
8		172.0	172.0
9		168.0	242.0
10		231.0	
11		278.0	
12		178.0	
13			
14			
15			
16			
17			
CYCLES	1.	338131.	200289.
AT	2.	373003.	202773.
MISS	3.	373291.	212933.

CYCLE NO.		N.C. CONTACT	N.O. CONTACT
INITIAL		142.0	337.0
1			32.8
2			253.0
3			338.0
4			338.0
5			338.0
6			320.0
7			35.9
8			151.0
9			251.0
10			338.0
11			338.0
12			
13			
14			
15			
16			
17			
CYCLES	1.	45.	337577.
AT	2.	78.	337578.
MISS	3.	79.	338424.

CYCLE NO.		N.C. CONTACT	N.O. CONTACT
INITIAL		333.0	51.9
1		337.0	83.5
2		245.0	84.2
3		262.0	181.0
4		45.7	116.0
5		46.2	248.0
6		196.0	177.0
7		261.0	180.0
8		339.0	
9		22.2	
10		321.0	
11		338.0	
12		83.8	
13		338.0	
14		66.9	
15		11.8	
16		12.0	
17		22.9	
CYCLES	1.	736575.	80410.
AT	2.	779658.	179720.
MISS	3.	1405211.	179721.

CYCLE NO.		N.C. CONTACT	N.O. CONTACT
INITIAL		333.0	28.4
1		28.0	80.9
2		23.0	48.0
3		26.1	64.0
4			
5			
6			
7			
8			
9			
10			
11			
12			
13			
14			
15			
16			
17			
CYCLES	1.	1254.	10849.
AT	2.	1255.	10850.
MISS	3.	1274.	10851.

CYCLE NO.	N.C. CONTACT	N.O. CONTACT
INITIAL	262.0	251.0
1	45.1	290.0
2		34.2
3		12.3
4		20.0
5		35.6
6		45.8
7		37.1
8		53.0
9		333.0
10		333.0
11		232.0
12		
13		
14		
15		
16		
17		
CYCLES 1.	176.	339589.
AT 2.	177.	339590.
MISS 3.	178.	339591.

CYCLE NO.	N.C. CONTACT	N.O. CONTACT
INITIAL	292.0	83.1
1	73.2	81.6
2	35.9	82.4
3	17.8	83.1
4		
5		
6		
7		
8		
9		
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12		
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14		
15		
16		
17		
CYCLES 1.	1001.	11088.
AT 2.	1002.	11089.
MISS 3.	1003.	11090.

CYCLE NO.	N.C. CONTACT	N.O. CONTACT
INITIAL	312.0	152.0
1	43.2	240.0
2	66.4	61.5
3	43.2	70.0
4		12.0
5		
6		
7		
8		
9		
10		
11		
12		
13		
14		
15		
16		
17		
CYCLES 1.	504.	92828.
AT 2.	838.	92829.
MISS 3.	893.	92830.

CYCLE NO.	N.C. CONTACT	N.O. CONTACT
INITIAL	186.0	140.0
1	84.1	183.0
2	55.2	156.0
3	48.8	84.2
4		84.2
5		22.1
6		
7		
8		
9		
10		
11		
12		
13		
14		
15		
16		
17		
CYCLES 1.	5112.	86020.
AT 2.	5442.	88080.
MISS 3.	5514.	90795.

CYCLE NO.	N.C. CONTACT	N.O. CONTACT
INITIAL	83.9	147.0
1	43.9	63.4
2	35.1	22.2
3	44.0	21.7
4		4.9
5		
6		
7		
8		
9		
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11		
12		
13		
14		
15		
16		
17		
CYCLES 1.	1378.	54070.
AT 2.	1379.	54733.
MISS 3.	1380.	54750.

CYCLE NO.	N.C. CONTACT	N.O. CONTACT
INITIAL	289.0	162.0
1		222.0
2		84.0
3		47.6
4		13.5
5		
6		
7		
8		
9		
10		
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12		
13		
14		
15		
16		
17		
CYCLES 1.	28.	42716.
AT 2.	29.	42717.
MISS 3.	30.	42718.

CYCLE NO.	N.C. CONTACT	N.O. CONTACT
INITIAL	340.0	240.0
1	64.0	77.1
2	58.7	142.0
3	41.3	83.5
4		60.2
5		13.1
6		22.3
7		4.4
8		22.2
9		11.2
10		21.3
11		84.2
12		34.8
13		59.5
14		
15		
16		
17		
CYCLES 1.	1583.	98491.
AT 2.	1584.	315988.
MISS 3.	1585.	480134.

CYCLE NO.	N.C. CONTACT	N.O. CONTACT
INITIAL	11.7	150.0
1	84.2	220.0
2		198.0
3		209.0
4		168.0
5		219.0
6		84.5
7		238.0
8		140.0
9		84.1
10		229.0
11		
12		
13		
14		
15		
16		
17		
CYCLES 1.	125.	189739.
AT 2.	143.	191439.
MISS 3.	162.	234828.

CYCLE NO.		N.C. CONTACT	N.O. CONTACT
INITIAL		331.0	243.0
1		274.0	338.0
2		69.1	200.0
3		37.0	261.0
4		38.2	70.7
5		41.6	206.0
6		64.3	233.0
7		22.7	333.0
8		272.0	84.0
9		77.0	
10			
11			
12			
13			
14			
15			
16			
17			
CYCLES	1.	218120.	193789.
AT	2.	218121.	202501.
MISS	3.	218122.	202502.

CYCLE NO.		N.C. CONTACT	N.O. CONTACT
INITIAL		332.0	43.0
1		332.0	147.0
2		79.5	83.9
3		84.0	84.0
4			8.7
5			
6			
7			
8			
9			
10			
11			
12			
13			
14			
15			
16			
17			
CYCLES	1.	2130.	57201.
AT	2.	2131.	57768.
MISS	3.	2132.	60873.

CYCLE NO.		N.C. CONTACT	N.O. CONTACT
INITIAL		300.0	188.0
1		83.8	235.0
2		22.9	148.0
3		23.0	216.0
4			44.8
5			
6			
7			
8			
9			
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11			
12			
13			
14			
15			
16			
17			
CYCLES	1.	4747.	31324.
AT	2.	4748.	31325.
MISS	3.	4749.	31326.

CYCLE NO.		N.C. CONTACT	N.O. CONTACT
INITIAL		150.0	160.0
1		69.9	208.0
2		49.8	195.0
3		36.7	83.5
4			14.8
5			22.8
6			152.0
7			233.0
8			148.0
9			152.0
10			172.0
11			23.5
12			36.5
13			
14			
15			
16			
17			
CYCLES	1.	4688.	366714.
AT	2.	4689.	366733.
MISS	3.	4690.	366734.

CYCLE NO.	N.C. CONTACT	N.O. CONTACT
INITIAL	223.0	216.0
1	180.0	49.3
2	48.0	62.5
3	59.8	79.0
4		12.5
5		
6		
7		
8		
9		
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11		
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14		
15		
16		
17		
CYCLES 1.	749.	14654.
AT 2.	2696.	14655.
MISS 3.	4853.	14674.

CYCLE NO.	N.C. CONTACT	N.O. CONTACT
INITIAL	161.0	213.0
1	146.0	337.0
2	36.9	295.0
3	189.0	31.3
4	147.0	337.0
5	170.0	
6	209.0	
7	22.1	
8		
9		
10		
11		
12		
13		
14		
15		
16		
17		
CYCLES 1.	165654.	17123.
AT 2.	165655.	24188
MISS 3.	165656.	24189.

CYCLE NO.	N.C. CONTACT	N.O. CONTACT
INITIAL	331.0	216.0
1	331.0	78.1
2		73.5
3		83.8
4		
5		
6		
7		
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9		
10		
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12		
13		
14		
15		
16		
17		
CYCLES 1.	412.	2183.
AT 2.	413.	2184.
MISS 3.	449.	2185.

CYCLE NO.	N.C. CONTACT	N.O. CONTACT
INITIAL	330.0	83.6
1	330.0	144.0
2	330.0	106.0
3	330.0	83.7
4	69.7	148.0
5	29.7	69.2
6	20.0	
7		
8		
9		
10		
11		
12		
13		
14		
15		
16		
17		
CYCLES 1.	85508.	69481.
AT 2.	129531.	91280.
MISS 3.	129559.	92073.

CYCLE NO.		N.C. CONTACT	N.O. CONTACT
INITIAL		15.3	327.0
1		16.2	260.0
2		83.5	200.0
3		328.0	140.0
4		22.8	76.9
5			
6			
7			
8			
9			
10			
11			
12			
13			
14			
15			
16			
17			
CYCLES	1.	71026.	67677.
AT	2.	71027.	67678.
MISS	3.	71028.	67698.

CYCLE NO.		N.C. CONTACT	N.O. CONTACT
INITIAL		337.0	142.0
1		338.0	145.0
2			209.0
3			178.0
4			158.0
5			130.0
6			64.5
7			
8			
9			
10			
11			
12			
13			
14			
15			
16			
17			
CYCLES	1.	103.	150149.
AT	2.	159.	150150.
MISS	3.	214.	150151.

CYCLE NO.		N.C. CONTACT	N.O. CONTACT
INITIAL		340.0	84.1
1		59.2	60.0
2		58.8	23.9
3		51.1	35.2
4			7.8
5			
6			
7			
8			
9			
10			
11			
12			
13			
14			
15			
16			
17			
CYCLES	1.	2215.	32588.
AT	2.	2360.	32589.
MISS	3.	2361.	32590.

CYCLE NO.		N.C. CONTACT	N.O. CONTACT
INITIAL		333.0	84.0
1		70.9	71.6
2		13.7	55.6
3		16.8	84.0
4			18.4
5			147.0
6			138.0
7			54.7
8			
9			
10			
11			
12			
13			
14			
15			
16			
17			
CYCLES	1.	1100.	175338.
AT	2.	1124.	175820.
MISS	3.	1280.	175950.

CYCLE NO.	N.C. CONTACT	N.O. CONTACT
INITIAL	24.0	232.0
1	51.8	202.0
2	56.9	148.0
3	58.0	159.0
4	83.8	194.0
5		
6		
7		
8		
9		
10		
11		
12		
13		
14		
15		
16		
17		
CYCLES 1.	62030.	32101.
AT 2.	62031.	32102.
MISS 3.	62050.	32103.

CYCLE NO.	N.C. CONTACT	N.O. CONTACT
INITIAL	200.0	55.0
1		30.0
2		44.1
3		54.1
4		37.8
5		36.0
6		22.2
7		11.3
8		21.6
9		59.7
10		22.7
11		84.2
12		
13		
14		
15		
16		
17		
CYCLES 1.	58.	149110.
AT 2.	59.	160945.
MISS 3.	60.	249752.

CYCLE NO.	N.C. CONTACT	N.O. CONTACT
INITIAL	339.0	206.0
1	66.8	193.0
2		84.0
3		146.0
4		
5		
6		
7		
8		
9		
10		
11		
12		
13		
14		
15		
16		
17		
CYCLES 1.	39.	10760.
AT 2.	80.	10761.
MISS 3.	419.	10778.

CYCLE NO.	N.C. CONTACT	N.O. CONTACT
INITIAL	261.0	137.0
1	181.0	188.0
2	292.0	212.0
3	200.0	190.0
4	265.0	249.0
5	310.0	243.0
6	270.0	220.0
7	308.0	
8		
9		
10		
11		
12		
13		
14		
15		
16		
17		
CYCLES 1.	167351.	149789.
AT 2.	167380.	149790.
MISS 3.	167423.	149791.

CYCLE NO.		N.C. CONTACT	N.O. CONTACT
INITIAL		332.0	199.0
1		268.0	100.0
2		53.5	164.0
3		51.5	148.0
4		50.9	138.0
5		84.1	
6		264.0	
7		271.0	
8		238.0	
9		73.0	
10		338.0	
11		169.0	
12		152.0	
13			
14			
15			
16			
17			
CYCLES	1.	290635.	46743.
AT	2.	358378.	46744.
MISS	3.	447880.	46745.

CYCLE NO.		N.C. CONTACT	N.O. CONTACT
INITIAL		286.0	139.0
1		149.0	99.0
2		74.3	140.0
3		56.9	200.0
4		44.8	177.0
5		140.0	185.0
6		151.0	211.0
7			175.0
8			194.0
9			202.0
10			198.0
11			161.0
12			200.0
13			200.0
14			
15			
16			
17			
CYCLES	1.	136149.	304631.
AT	2.	136150.	495783.
MISS	3.	136176.	500006.

CYCLE NO.		N.C. CONTACT	N.O. CONTACT
INITIAL		247.0	240.0
1		77.6	148.0
2		34.8	145.0
3		74.0	188.0
4			23.2
5			34.5
6			143.0
7			190.0
8			218.0
9			140.0
10			152.0
11			144.0
12			205.0
13			
14			
15			
16			
17			
CYCLES	1.	1940.	112879.
AT	2.	1981.	394144.
MISS	3.	1999.	394280.

CYCLE NO.		N.C. CONTACT	N.O. CONTACT
INITIAL		338.0	216.0
1		82.0	51.1
2			51.3
3			83.6
4			
5			
6			
7			
8			
9			
10			
11			
12			
13			
14			
15			
16			
17			
CYCLES	1.	151.	6679.
AT	2.	167.	6680.
MISS	3.	168.	6699.

CYCLE NO.		N.C. CONTACT	N.O. CONTACT
INITIAL		338.0	209.0
1		232.0	271.0
2		37.4	211.0
3		21.9	216.0
4		30.0	150.0
5		84.1	161.0
6		338.0	260.0
7		325.0	284.0
8		338.0	211.0
9		339.0	
10		339.0	
11		304.0	
12		156.0	
13			
14			
15			
16			
17			
CYCLES	1.	293847.	199398.
AT	2.	293848.	199399.
MISS	3.	401926.	199419.

CYCLE NO.		N.C. CONTACT	N.O. CONTACT
INITIAL		334.0	202.0
1		71.7	84.0
2			79.3
3			83.9
4			16.1
5			20.0
6			57.4
7			53.8
8			32.3
9			24.0
10			55.8
11			81.2
12			225.0
13			
14			
15			
16			
17			
CYCLES	1.	274.	405750.
AT	2.	275	438290.
MISS	3.	276.	438291.

CYCLE NO.		N.C. CONTACT	N.O. CONTACT
INITIAL		330.0	158.0
1		330.0	148.0
2		141.0	149.0
3		83.8	181.0
4		34.9	71.3
5		84.0	173.0
6			210.0
7			
8			
9			
10			
11			
12			
13			
14			
15			
16			
17			
CYCLES	1.	97208.	113879.
AT	2.	97209.	113953.
MISS	3.	97210.	113988.

CYCLE NO.		N.C. CONTACT	N.O. CONTACT
INITIAL		328.0	206.0
1		72.5	148.0
2		70.6	67.0
3		125.0	79.8
4			34.2
5			14.3
6			50.2
7			138.0
8			307.0
9			280.0
10			211.0
11			212.0
12			227.0
13			296.0
14			209.0
15			
16			
17			
CYCLES	1.	1596.	562683.
AT	2.	1597.	562684.
MISS	3.	1598.	562685.

CYCLE NO.		N.C. CONTACT	N.O. CONTACT
INITIAL		198.0	336.0
1		76.0	284.0
2		54.3	175.0
3			338.0
4			13.1
5			22.0
6			18.0
7			39.3
8			147.0
9			
10			
11			
12			
13			
14			
15			
16			
17			
CYCLES	1.	144.	180047.
AT	2.	552.	180048.
MISS	3.	569.	180049.

CYCLE NO.		N.C. CONTACT	N.O. CONTACT
INITIAL		267.0	145.0
1		240.0	262.0
2		84.0	124.0
3		35.6	127.0
4		327.0	61.9
5		34.4	140.0
6		209.0	169.0
7		209.0	
8		37.0	
9		338.0	
10			
11			
12			
13			
14			
15			
16			
17			
CYCLES	1.	226859.	148741.
AT	2.	226860.	148742.
MISS	3.	226880.	148743.

CYCLE NO.		N.C. CONTACT	N.O. CONTACT
INITIAL		299.0	188.0
1		175.0	150.0
2		54.1	84.0
3		37.8	148.0
4			36.0
5			275.0
6			228.0
7			227.0
8			177.0
9			193.0
10			
11			
12			
13			
14			
15			
16			
17			
CYCLES	1.	6068.	210848.
AT	2.	6324.	211406.
MISS	3.	6325.	211478.

CYCLE NO.		N.C. CONTACT	N.O. CONTACT
INITIAL		330.0	145.0
1		147.0	83.5
2		83.6	74.4
3		100.0	132.0
4		55.9	63.1
5		84.0	190.0
6		100.0	150.0
7		309.0	220.0
8		336.0	264.0
9		209.0	
10			
11			
12			
13			
14			
15			
16			
17			
CYCLES	1.	210289.	207861.
AT	2.	210290.	207862.
MISS	3.	210291.	207863.

CYCLE NO.		N.C. CONTACT	N.O. CONTACT
INITIAL		328.0	83.2
1		68.7	54.1
2			81.2
3			70.0
4			10.7
5			21.0
6			21.6
7			24.0
8			44.8
9			83.5
10			68.8
11			
12			
13			
14			
15			
16			
17			
CYCLES	1.	196.	227828.
AT	2.	197.	227829.
MISS	3.	198.	227830.

CYCLE NO.		N.C. CONTACT	N.O. CONTACT
INITIAL		339.0	226.0
1		79.2	208.0
2			216.0
3			142.0
4			311.0
5			
6			
7			
8			
9			
10			
11			
12			
13			
14			
15			
16			
17			
CYCLES	1.	118.	60707.
AT	2.	119.	60708.
MISS	3.	264.	60720.

CYCLE NO.		N.C. CONTACT	N.O. CONTACT
INITIAL		338.0	154.0
1		338.0	231.0
2		338.0	213.0
3		75.0	166.0
4		84.0	64.9
5		193.0	147.0
6		46.1	146.0
7		338.0	
8		338.0	
9		84.0	
10			
11			
12			
13			
14			
15			
16			
17			
CYCLES	1.	224917.	118867.
AT	2.	224918.	118868.
MISS	3.	224919.	138811.

CYCLE NO.		N.C. CONTACT	N.O. CONTACT
INITIAL		294.0	219.0
1		84.0	178.0
2		100.0	83.9
3		79.1	102.0
4		34.9	62.8
5		302.0	200.0
6		84.0	213.0
7		280.0	265.0
8		322.0	200.0
9		16.6	
10		248.0	
11		232.0	
12			
13			
14			
15			
16			
17			
CYCLES	1.	336173.	205137.
AT	2.	336174.	205138.
MISS	3.	336175.	205139.

CYCLE NO.		N.C. CONTACT	N.O. CONTACT
INITIAL		230.0	200.0
1		65.3	187.0
2		51.8	83.8
3		50.0	248.0
4			16.0
5			21.8
6			63.1
7			218.0
8			
9			
10			
11			
12			
13			
14			
15			
16			
17			
CYCLES	1.	4098.	179657.
AT	2.	4099.	179658.
MISS	3.	4118.	179659.

CYCLE NO.		N.C. CONTACT	N.O. CONTACT
INITIAL		328.0	208.0
1		193.0	143.0
2		62.8	148.0
3		70.0	139.0
4		38.7	16.2
5		230.0	68.9
6		148.0	218.0
7		328.0	189.0
8		273.0	198.0
9		70.3	187.0
10		67.1	152.0
11		84.0	212.0
12		202.0	
13			
14			
15			
16			
17			
CYCLES	1.	384727.	180848.
AT	2.	384728.	257615.
MISS	3.	384729.	337289.

6.7.3 TYPE C RELAYS, ACCELERATED TEST CONDITIONS WITH I.M. PRODUCTS MEASUREMENTS - RELAYS No. 1 THROUGH 15.

The data from the first 15 relays which were tested at accelerated conditions with I.M. products measured is given in the next 4 pages. The codes 1-17 refer to the same number of test cycles given in Subsection 6.7.1.

CYCLE NO.		N.C. CONTACT	N.O. CONTACT
INITIAL		2.82	2.92
1		2.33	2.95
2			2.88
3			2.93
4			3.03
5			
6			
7			
8			
9			
10			
11			
12			
13			
14			
15			
16			
17			
CYCLES	1.	290.	12311.
AT	2.	329.	13501.
MISS	3.	402.	13502.

CYCLE NO.		N.C. CONTACT	N.O. CONTACT
INITIAL		2.80	2.97
1		2.64	3.00
2		2.80	2.95
3		2.68	3.00
4			
5			
6			
7			
8			
9			
10			
11			
12			
13			
14			
15			
16			
17			
CYCLES	1.	1228.	831.
AT	2.	1240.	832.
MISS	3.	1280.	833.

CYCLE NO.		N.C. CONTACT	N.O. CONTACT
INITIAL		2.71	2.84
1		2.45	2.88
2		2.48	
3		2.39	
4			
5			
6			
7			
8			
9			
10			
11			
12			
13			
14			
15			
16			
17			
CYCLES	1.	2666.	238.
AT	2.	2667.	239.
MISS	3.	2668.	259.

CYCLE NO.		N.C. CONTACT	N.O. CONTACT
INITIAL		2.70	3.01
1		2.72	3.02
2		2.70	2.95
3		2.48	
4			
5			
6			
7			
8			
9			
10			
11			
12			
13			
14			
15			
16			
17			
CYCLES	1.	10630.	516.
AT	2.	10660.	517.
MISS	3.	10699.	518.

CYCLE NO.		N.C. CONTACT	N.O. CONTACT
INITIAL		2.52	3.01
1		2.74	2.90
2		2.67	2.85
3		2.62	
4			
5			
6			
7			
8			
9			
10			
11			
12			
13			
14			
15			
16			
17			
CYCLES	1.	3690.	518.
AT	2.	3691.	537.
MISS	3.	3692.	538.

CYCLE NO.		N.C. CONTACT	N.O. CONTACT
INITIAL		2.79	2.46
1		2.71	2.44
2			2.43
3			2.44
4			
5			
6			
7			
8			
9			
10			
11			
12			
13			
14			
15			
16			
17			
CYCLES	1.	152.	951.
AT	2.	330.	1003.
MISS	3.	443.	1004.

CYCLE NO.		N.C. CONTACT	N.O. CONTACT
INITIAL		2.92	3.00
1		2.74	2.93
2		2.87	2.91
3		2.87	2.93
4			
5			
6			
7			
8			
9			
10			
11			
12			
13			
14			
15			
16			
17			
CYCLES	1.	518.	1149.
AT	2.	519.	1981.
MISS	3.	771.	2010.

CYCLE NO.		N.C. CONTACT	N.O. CONTACT
INITIAL		2.71	2.72
1		2.45	2.69
2			2.68
3			
4			
5			
6			
7			
8			
9			
10			
11			
12			
13			
14			
15			
16			
17			
CYCLES	1.	442.	571.
AT	2.	443.	572.
MISS	3.	489.	573.

CYCLE NO.		N.C. CONTACT	N.O. CONTACT
INITIAL		2.76	2.74
1		2.79	2.70
2		2.80	2.79
3		2.78	2.65
4		2.86	2.68
5		2.82	
6			
7			
8			
9			
10			
11			
12			
13			
14			
15			
16			
17			
CYCLES	1.	103073.	31781.
AT	2.	103074.	51331.
MISS	3.	103075.	51380.

CYCLE NO.		N.C. CONTACT	N.O. CONTACT
INITIAL		2.48	2.73
1		2.31	2.85
2		2.39	2.82
3			2.80
4			
5			
6			
7			
8			
9			
10			
11			
12			
13			
14			
15			
16			
17			
CYCLES	1.	518.	1023.
AT	2.	519.	2214.
MISS	3.	734.	3089.

CYCLE NO.		N.C. CONTACT	N.O. CONTACT
INITIAL		2.96	2.91
1		3.08	2.82
2		3.01	2.93
3		3.01	2.99
4			
5			
6			
7			
8			
9			
10			
11			
12			
13			
14			
15			
16			
17			
CYCLES	1.	1037.	1691.
AT	2.	1038.	1835.
MISS	3.	1039.	1851.

CYCLE NO.		N.C. CONTACT	N.O. CONTACT
INITIAL		2.63	2.77
1		2.76	2.84
2		2.73	2.82
3			2.83
4			
5			
6			
7			
8			
9			
10			
11			
12			
13			
14			
15			
16			
17			
CYCLES	1.	723.	742.
AT	2.	724.	1005.
MISS	3.	742.	2155.

CYCLE NO.	N.C. CONTACT	N.O. CONTACT
INITIAL	2.78	2.44
1	2.82	2.53
2	2.60	2.52
3	2.28	2.50
4		2.63
5		
6		
7		
8		
9		
10		
11		
12		
13		
14		
15		
16		
17		
CYCLES 1.	2748.	3142.
AT 2.	2944.	13548.
MISS 3.	2980.	13565.

CYCLE NO.	N.C. CONTACT	N.O. CONTACT
INITIAL	2.50	2.71
1	2.44	2.79
2	2.59	2.79
3	2.61	2.77
4		
5		
6		
7		
8		
9		
10		
11		
12		
13		
14		
15		
16		
17		
CYCLES 1.	1058.	633.
AT 2.	1169.	634.
MISS 3.	1169.	784.

CYCLE NO.	N.C. CONTACT	N.O. CONTACT
INITIAL	2.74	2.62
1	2.83	2.60
2	2.71	2.60
3	2.69	2.59
4		2.84
5		
6		
7		
8		
9		
10		
11		
12		
13		
14		
15		
16		
17		
CYCLES 1.	2551.	13565.
AT 2.	5430.	32742.
MISS 3.	11924.	32743.

6.7.4 TYPCE C RELAYS, ACCELERATED TEST CONDITIONS WITH I.M. PRODUCTS MEASUREMENTS - RELAYS NO. 16 THROUGH 50.

The data from the last 35 relays tested at accelerated conditions with I.M. products measured is given in the next 9 pages. I.M. product readings were taken at more frequent intervals on this group than on the first 15 relays, because the relays failed more quickly than they were expected to fail. The codes 1-17 refer here to the following number of test cycles:

1. 350 cycles
2. 380 cycles
3. 430 cycles
4. 490 cycles
5. 560 cycles
6. 720 cycles
7. 960 cycles
8. 1,150 cycles
9. 1,350 cycles
10. 1,600 cycles
11. 2,100 cycles
12. 3,700 cycles
13. 9,600 cycles
14. 19,000 cycles
15. 35,000 cycles
16. 88,000 cycles
17. 107,000 cycles

CYCLE NO.		N.C. CONTACT	N.O. CONTACT
INITIAL		2.57	2.23
1		2.57	2.13
2		2.58	2.19
3		2.50	2.15
4		2.50	2.14
5		2.49	2.13
6			2.11
7			2.21
8			2.15
9			2.15
10			2.13
11			2.19
12			2.21
13			2.23
14			2.30
15			2.35
16			
17			
CYCLES	1.	112.	43760.
AT	2.	131.	43761.
MISS	3.	960.	43762.

CYCLE NO.		N.C. CONTACT	N.O. CONTACT
INITIAL		2.77	2.82
1		2.71	2.75
2		2.74	2.79
3		2.68	2.73
4		2.64	2.75
5		2.62	2.77
6		2.62	2.77
7		2.61	2.75
8		2.76	2.78
9		2.71	2.80
10		2.76	2.81
11		2.72	2.81
12		2.72	2.85
13			
14			
15			
16			
17			
CYCLES	1.	3729.	3757.
AT	2.	3730.	3758.
MISS	3.	3731.	3759.

CYCLE NO.		N.C. CONTACT	N.O. CONTACT
INITIAL		2.46	2.81
1		2.38	2.71
2		2.41	2.72
3		2.24	2.65
4		2.23	2.63
5		2.22	2.60
6		2.32	
7		2.33	
8		2.33	
9		2.21	
10		2.45	
11		2.42	
12		2.43	
13			
14			
15			
16			
17			
CYCLES	1.	3729.	563.
AT	2.	3730.	564.
MISS	3.	3731.	615.

CYCLE NO.		N.C. CONTACT	N.O. CONTACT
INITIAL		2.57	2.76
1		2.52	2.52
2		2.41	2.65
3		2.48	2.61
4		2.47	2.55
5		2.47	2.52
6		2.52	2.58
7		2.45	
8		2.70	
9		2.41	
10		2.41	
11			
12			
13			
14			
15			
16			
17			
CYCLES	1.	1974.	772.
AT	2.	1975.	790.
MISS	3.	1991.	791.

CYCLE NO.		N.C. CONTACT	N.O. CONTACT
INITIAL		2.53	2.71
1		2.52	2.61
2		2.52	2.62
3		2.47	2.61
4		2.54	2.63
5		2.56	2.65
6		2.59	2.62
7		2.58	2.67
8			2.61
9			2.61
10			2.64
11			2.60
12			2.67
13			2.69
14			
15			
16			
17			
CYCLES	1.	1003.	8639.
AT	2.	1019.	9709.
MISS	3.	1020.	9710.

CYCLE NO.		N.C. CONTACT	N.O. CONTACT
INITIAL		2.79	2.76
1		2.69	2.71
2		2.75	2.74
3		2.59	2.71
4		2.67	2.71
5		2.70	2.71
6		2.80	2.74
7		2.68	2.72
8		2.48	2.69
9			2.68
10			2.68
11			
12			
13			
14			
15			
16			
17			
CYCLES	1.	1177.	1968.
AT	2.	1178.	1969.
MISS	3.	1179.	1970.

CYCLE NO.		N.C. CONTACT	N.O. CONTACT
INITIAL		2.49	2.57
1		2.45	2.50
2		2.39	2.58
3		2.42	2.49
4		2.46	2.40
5		2.50	2.36
6		2.52	2.53
7		2.45	2.58
8			2.43
9			2.42
10			2.63
11			2.57
12			
13			
14			
15			
16			
17			
CYCLES	1.	568.	1995.
AT	2.	569.	2322.
MISS	3.	970.	2323.

CYCLE NO.		N.C. CONTACT	N.O. CONTACT
INITIAL		2.72	2.92
1		2.50	2.91
2		2.59	2.91
3		2.55	2.87
4		2.56	2.85
5		2.57	2.83
6		2.46	2.86
7			2.88
8			2.91
9			2.82
10			2.84
11			
12			
13			
14			
15			
16			
17			
CYCLES	1.	748.	1871.
AT	2.	749.	1905.
MISS	3.	750.	1906.

CYCLE NO.	N.C. CONTACT	N.O. CONTACT
INITIAL	2.52	2.79
1	2.48	2.79
2	2.50	2.77
3	2.38	2.78
4	2.40	2.76
5	2.43	2.75
6	2.48	2.81
7	2.48	2.73
8	2.32	2.72
9	2.32	2.68
10	2.49	2.87
11	2.49	2.87
12		
13		
14		
15		
16		
17		
CYCLES 1.	1639.	2323.
AT 2.	2124.	2341.
MISS 3.	2125.	2348.

CYCLE NO.	N.C. CONTACT	N.O. CONTACT
INITIAL	2.67	2.73
1	2.59	2.60
2	2.58	2.66
3	2.39	2.57
4	2.35	2.58
5	2.28	2.59
6	2.45	2.62
7		2.61
8		2.57
9		2.61
10		2.63
11		2.64
12		
13		
14		
15		
16		
17		
CYCLES 1.	730.	1570.
AT 2.	731.	1818.
MISS 3.	750.	2151.

CYCLE NO.	N.C. CONTACT	N.O. CONTACT
INITIAL	2.59	2.47
1	2.48	2.42
2	2.59	2.40
3	2.59	2.47
4	2.58	2.47
5	2.58	2.46
6	2.55	2.43
7	2.53	2.38
8	2.53	2.42
9	2.48	2.43
10	2.48	2.48
11	2.45	
12	2.59	
13	2.60	
14		
15		
16		
17		
CYCLES 1.	8809.	1714.
AT 2.	9599.	2107.
MISS 3.	9600.	2108.

CYCLE NO.	N.C. CONTACT	N.O. CONTACT
INITIAL	2.59	2.92
1	2.42	2.82
2	2.49	2.80
3	2.43	2.83
4	2.46	2.83
5	2.50	2.84
6	2.42	2.79
7	2.44	2.78
8	2.40	2.79
9	2.57	2.79
10	2.57	2.80
11	2.53	
12		
13		
14		
15		
16		
17		
CYCLES 1.	3022.	1677.
AT 2.	3023.	1678.
MISS 3.	3024.	2108.

CYCLE NO.	N.C. CONTACT	N.O. CONTACT
INITIAL	2.61	2.69
1	2.59	2.60
2	2.59	2.59
3	2.59	2.62
4	2.59	2.62
5	2.59	2.62
6	2.39	2.61
7	2.47	2.55
8	2.44	2.61
9	2.60	2.55
10	2.60	2.57
11		
12		
13		
14		
15		
16		
17		
CYCLES 1.	2106.	2106.
AT 2.	2107.	2107.
MISS 3.	2108.	2108.

CYCLE NO.	N.C. CONTACT	N.O. CONTACT
INITIAL	2.70	2.75
1	2.55	2.72
2	2.54	2.72
3	2.61	2.78
4	2.61	2.78
5	2.61	2.77
6	2.50	2.72
7	2.42	2.71
8	2.59	2.72
9	2.58	2.72
10	2.58	2.71
11	2.51	2.71
12	2.40	2.79
13		2.87
14		2.90
15		
16		
17		
CYCLES 1.	2108.	27040.
AT 2.	6729.	27063.
MISS 3.	6730.	27073.

CYCLE NO.	N.C. CONTACT	N.O. CONTACT
INITIAL	2.67	3.29
1	2.44	3.18
2	2.38	3.19
3	2.30	3.21
4	2.37	3.20
5	2.42	3.19
6	2.38	3.16
7	2.40	
8	2.41	
9	2.48	
10	2.43	
11		
12		
13		
14		
15		
16		
17		
CYCLES 1.	2059.	719.
AT 2.	2075.	720.
MISS 3.	2076.	790.

CYCLE NO.	N.C. CONTACT	N.O. CONTACT
INITIAL	2.79	2.81
1	2.61	2.81
2	2.62	2.81
3	2.58	2.81
4	2.62	2.71
5	2.69	2.81
6		2.81
7		2.81
8		2.81
9		2.81
10		2.81
11		2.81
12		
13		
14		
15		
16		
17		
CYCLES 1.	377.	2528.
AT 2.	669.	2529.
MISS 3.	718.	2539.

CYCLE NO.		N.C. CONTACT	N.O. CONTACT
INITIAL		2.90	2.58
1		2.68	2.49
2		2.45	2.52
3		2.83	2.54
4		2.83	2.51
5		2.85	2.53
6		2.86	2.55
7		2.86	2.57
8		2.86	2.58
9		2.83	2.56
10		2.83	2.55
11		2.69	2.51
12		2.82	2.61
13			
14			
15			
16			
17			
CYCLES	1.	3718.	3797.
AT	2.	3719.	3798.
MISS	3.	3720.	3799.

CYCLE NO.		N.C. CONTACT	N.O. CONTACT
INITIAL		2.59	2.84
1		2.42	2.83
2		2.56	2.83
3		2.53	2.82
4		2.42	2.82
5		2.53	2.92
6		2.54	2.82
7		2.53	2.97
8		2.50	2.84
9		2.53	2.83
10		2.39	2.84
11			2.83
12			2.85
13			
14			
15			
16			
17			
CYCLES	1.	1511.	3762.
AT	2.	1631.	3763.
MISS	3.	1632.	3764.

CYCLE NO.		N.C. CONTACT	N.O. CONTACT
INITIAL		2.78	2.60
1		2.80	2.60
2		2.79	2.61
3		2.78	2.60
4		2.78	2.59
5		2.79	2.60
6		2.79	2.62
7		2.77	2.60
8		2.73	2.63
9		2.80	2.63
10		2.80	2.64
11		2.80	2.64
12		2.82	2.64
13		2.84	2.69
14		2.90	2.75
15		2.86	
16			
17			
CYCLES	1.	49558.	14749.
AT	2.	49559.	24268.
MISS	3.	49560.	24269.

CYCLE NO.		N.C. CONTACT	N.O. CONTACT
INITIAL		2.57	2.48
1		2.54	2.46
2		2.52	2.45
3		2.57	2.43
4		2.57	2.43
5		2.56	2.44
6		2.52	2.47
7		2.28	2.75
8		2.58	2.68
9			2.63
10			2.69
11			2.60
12			
13			
14			
15			
16			
17			
CYCLES	1.	1070.	718.
AT	2.	1198.	2528.
MISS	3.	1199.	2529.

CYCLE NO.	N.C. CONTACT	N.O. CONTACT
INITIAL	2.61	2.71
1	2.48	2.70
2	2.57	2.69
3	2.51	2.65
4	2.54	2.69
5	2.58	2.69
6		2.63
7		2.65
8		
9		
10		
11		
12		
13		
14		
15		
16		
17		
CYCLES 1.	490.	930.
AT 2.	716.	931.
MISS 3.	717.	990.

CYCLE NO.	N.C. CONTACT	N.O. CONTACT
INITIAL	2.58	2.82
1	2.53	2.79
2	2.54	2.81
3	2.50	2.79
4	2.48	2.81
5	2.59	2.82
6	2.59	2.82
7	2.54	2.76
8	2.54	2.73
9	2.49	2.82
10	2.53	
11	2.49	
12		
13		
14		
15		
16		
17		
CYCLES 1.	3392.	1346.
AT 2.	3500.	1475.
MISS 3.	3589.	1493.

CYCLE NO.	N.C. CONTACT	N.O. CONTACT
INITIAL	2.31	2.52
1	2.26	2.48
2	2.28	2.45
3	2.24	2.47
4	2.26	2.48
5	2.22	2.51
6	2.26	2.48
7	2.31	2.38
8	2.22	2.45
9	2.23	2.48
10	2.28	2.49
11	2.23	
12		
13		
14		
15		
16		
17		
CYCLES 1.	3371.	1676.
AT 2.	3372.	1677.
MISS 3.	3373.	1678.

CYCLE NO.	N.C. CONTACT	N.O. CONTACT
INITIAL	2.52	2.63
1	2.45	2.63
2	2.52	2.64
3	2.42	2.62
4	2.49	2.65
5	2.51	2.67
6	2.53	2.65
7	2.43	2.59
8	2.43	2.61
9	2.40	2.62
10	2.48	2.65
11	2.43	2.63
12	2.48	2.62
13	2.50	
14	2.51	
15	2.49	
16	2.53	
17		
CYCLES 1.	60649.	6683.
AT 2.	88025.	7976.
MISS 3.	88026.	8101.

CYCLE NO.		N.C. CONTACT	N.O. CONTACT
INITIAL		2.78	2.64
1		2.78	2.62
2		2.80	2.62
3		2.80	2.58
4		2.80	2.61
5		2.81	2.64
6		2.75	2.64
7		2.68	2.62
8		2.73	
9		2.68	
10		2.76	
11		2.74	
12		2.78	
13			
14			
15			
16			
17			
CYCLES	1.	3499.	961.
AT	2.	3748.	1150.
MISS	3.	4536.	1151.

CYCLE NO.		N.C. CONTACT	N.O. CONTACT
INITIAL		2.44	2.69
1		2.28	2.64
2		2.43	2.63
3		2.33	2.62
4		2.38	2.62
5		2.25	2.61
6		2.36	2.61
7		2.38	
8		2.28	
9		2.26	
10		2.45	
11		2.38	
12		2.38	
13			
14			
15			
16			
17			
CYCLES	1.	5285.	938.
AT	2.	5320.	960.
MISS	3.	5321.	961.

CYCLE NO.		N.C. CONTACT	N.O. CONTACT
INITIAL		2.52	2.61
1		2.41	2.68
2		2.49	2.62
3		2.49	2.59
4		2.47	2.62
5		2.50	2.63
6		2.49	2.63
7		2.49	2.62
8		2.40	2.63
9		2.33	2.66
10		2.42	2.63
11		2.48	2.67
12		2.40	2.69
13		2.34	2.72
14		2.70	2.81
15		2.71	2.88
16			
17			
CYCLES	1.	55903.	45538.
AT	2.	57521.	45539.
MISS	3.	57522.	45540.

CYCLE NO.		N.C. CONTACT	N.O. CONTACT
INITIAL		2.37	2.61
1		2.30	2.60
2		2.34	
3		2.23	
4		2.19	
5		2.12	
6		2.23	
7		2.23	
8		2.19	
9		2.22	
10		2.22	
11		2.23	
12		2.35	
13			
14			
15			
16			
17			
CYCLES	1.	7091.	382.
AT	2.	7092.	383.
MISS	3.	7110.	384.

CYCLE NO.		N.C. CONTACT	N.O. CONTACT
INITIAL		2.71	2.69
1		2.72	2.68
2		2.71	2.65
3		2.72	2.62
4		2.65	2.62
5		2.84	2.65
6		2.85	2.66
7		2.89	2.65
8		2.81	2.65
9		2.76	2.67
10		2.73	2.65
11			2.69
12			
13			
14			
15			
16			
17			
CYCLES	1.	1983.	2201.
AT	2.	2002.	2202.
MISS	3.	2018.	2203.

CYCLE NO.		N.C. CONTACT	N.O. CONTACT
INITIAL		2.54	2.52
1		2.54	2.56
2		2.52	2.49
3		2.45	2.49
4		2.47	2.49
5		2.40	2.52
6		2.45	2.53
7		2.52	2.53
8		2.48	
9		2.52	
10		2.41	
11		2.52	
12		2.52	
13			
14			
15			
16			
17			
CYCLES	1.	7763.	770.
AT	2.	7852.	961.
MISS	3.	7993.	981.

CYCLE NO.		N.C. CONTACT	N.O. CONTACT
INITIAL		2.41	2.64
1		2.38	2.58
2		2.42	2.55
3		2.42	2.56
4		2.39	2.53
5		2.43	2.53
6		2.31	2.53
7		2.39	2.56
8		2.44	2.55
9		2.45	2.55
10		2.38	2.55
11			2.57
12			
13			
14			
15			
16			
17			
CYCLES	1.	316.	1671.
AT	2.	688.	2190.
MISS	3.	1742.	2191.

CYCLE NO.		N.C. CONTACT	N.O. CONTACT
INITIAL		2.81	2.47
1		2.79	2.45
2		2.73	2.42
3		2.79	2.42
4		2.66	2.42
5		2.81	2.39
6		2.82	2.45
7		2.80	2.45
8		2.72	2.42
9		2.74	2.46
10		2.80	2.43
11		2.82	2.47
12		2.81	2.47
13		2.88	2.56
14			2.54
15			
16			
17			
CYCLES	1.	2190.	28338.
AT	2.	2191.	28352.
MISS	3.	9744.	28353.

CYCLE NO.		N.C. CONTACT	N.O. CONTACT
INITIAL		2.62	2.60
1		2.61	2.52
2		2.50	2.58
3		2.59	2.57
4		2.63	2.56
5		2.68	2.53
6		2.61	2.58
7		2.57	2.58
8		2.43	2.58
9		2.52	2.58
10		2.57	2.59
11		2.59	2.59
12		2.68	2.59
13		2.64	2.68
14		2.82	2.76
15		2.73	
16		2.77	
17		2.72	
CYCLES	1.	107050.	17090.
AT	2.	172891.	19028.
MISS	3.	172898.	22340.

CYCLE NO.		N.C. CONTACT	N.O. CONTACT
INITIAL		2.84	2.77
1		2.75	2.67
2		2.76	2.67
3		2.81	2.67
4		2.80	2.66
5		2.86	2.61
6		2.91	2.69
7		2.76	2.70
8		2.88	2.69
9		2.80	2.64
10		2.86	2.69
11		2.76	2.70
12			
13			
14			
15			
16			
17			
CYCLES	1.	3140.	1572.
AT	2.	3488.	2190.
MISS	3.	3570.	2191.

CYCLE NO.		N.C. CONTACT	N.O. CONTACT
INITIAL		2.61	2.98
1		2.56	2.88
2		2.62	2.89
3		2.63	2.89
4		2.62	2.90
5		2.70	2.88
6		2.65	2.89
7		2.65	
8		2.58	
9		2.55	
10		2.60	
11		2.55	
12			
13			
14			
15			
16			
17			
CYCLES	1.	2748.	887.
AT	2.	2749.	888.
MISS	3.	2750.	889.

6.7.5 TYPE C RELAYS, ACCELERATED TEST CONDITIONS WITH C.R. MEASUREMENTS

The data from the 50 Type C relays tested at accelerated test conditions with C.R. measurements is given in the next 13 pages. The codes 1-17 refer to the same number of cycles as in Subsection 6.7.4.

CYCLE NO.		N.C. CONTACT	N.O. CONTACT
INITIAL		43.5	14.7
1		31.5	34.9
2		36.9	35.2
3		21.8	36.1
4		11.9	35.0
5		19.1	35.0
6		19.0	40.6
7		22.2	36.4
8		16.8	32.2
9		15.8	36.2
10		16.6	32.2
11		32.3	43.0
12		34.5	36.0
13			36.4
14			41.2
15			18.1
16			
17			
CYCLES	1.	1068.	78509.
AT	2.	2822.	78510.
MISS	3.	4008.	84961.

CYCLE NO.		N.C. CONTACT	N.O. CONTACT
INITIAL		38.8	41.7
1		24.7	43.4
2		21.5	42.1
3		16.1	28.8
4		16.6	36.2
5		11.2	45.1
6		11.4	40.8
7			49.3
8			26.8
9			26.3
10			38.6
11			
12			
13			
14			
15			
16			
17			
CYCLES	1.	919.	929.
AT	2.	920.	1598.
MISS	3.	921.	1766.

CYCLE NO.		N.C. CONTACT	N.O. CONTACT
INITIAL		50.0	34.5
1		21.1	38.6
2		18.8	32.8
3		17.9	33.6
4		20.0	34.8
5		17.0	35.0
6		11.4	37.0
7		11.7	20.0
8			38.6
9			45.8
10			27.8
11			
12			
13			
14			
15			
16			
17			
CYCLES	1.	976.	1870.
AT	2.	977.	1871.
MISS	3.	978.	1872.

CYCLE NO.		N.C. CONTACT	N.O. CONTACT
INITIAL		33.2	41.7
1		28.4	48.0
2		13.5	45.9
3		23.0	42.9
4		16.5	35.6
5		25.9	49.7
6		15.8	33.2
7		17.1	31.0
8		11.7	11.8
9		11.8	24.7
10		21.1	38.6
11		2.8	
12			
13			
14			
15			
16			
17			
CYCLES	1.	2072.	1627.
AT	2.	2090.	1891.
MISS	3.	2150.	1892.

CYCLE NO.	N.C. CONTACT	N.O. CONTACT
INITIAL	33.2	41.7
1	28.4	48.0
2	13.5	45.9
3	23.0	42.9
4	16.5	35.6
5	25.9	49.7
6	15.8	33.2
7	17.1	31.0
8	11.7	11.8
9	11.8	24.7
10	21.1	38.6
11	2.8	
12		
13		
14		
15		
16		
17		
CYCLES 1.	1676.	930.
AT 2.	1677.	1347.
MISS 3.	1678.	1491.

CYCLE NO.	N.C. CONTACT	N.O. CONTACT
INITIAL	17.8	35.2
1	15.8	26.8
2		24.0
3		29.0
4		33.8
5		21.9
6		39.1
7		25.2
8		29.8
9		36.0
10		36.0
11		34.6
12		
13		
14		
15		
16		
17		
CYCLES 1.	113.	938.
AT 2.	114.	1604.
MISS 3.	360.	2182.

CYCLE NO.	N.C. CONTACT	N.O. CONTACT
INITIAL	12.2	22.0
1	6.0	22.7
2	5.8	35.2
3	5.0	15.5
4	15.6	33.4
5	19.2	33.5
6	3.0	34.5
7	3.9	22.6
8	11.8	
9	18.1	
10	8.5	
11	8.4	
12		
13		
14		
15		
16		
17		
CYCLES 1.	2903,	718.
AT 2.	2921.	1114.
MISS 3.	3030.	1115.

CYCLE NO.	N.C. CONTACT	N.O. CONTACT
INITIAL	22.3	11.8
1	22.8	38.0
2	22.5	27.2
3	23.2	27.4
4	22.7	34.4
5	23.5	34.2
6	22.1	35.7
7	21.5	22.5
8	17.2	23.0
9	8.6	21.5
10	11.9	
11	12.1	
12	16.2	
13		
14		
15		
16		
17		
CYCLES 1.	4947.	939.
AT 2.	4948.	1579.
MISS 3.	5092.	1580.

CYCLE NO.	N.C. CONTACT	N.O. CONTACT
INITIAL	36.3	47.0
1	23.9	42.2
2	21.4	35.0
3	28.0	34.6
4	20.7	36.0
5	27.2	54.0
6	34.9	38.1
7	28.4	35.0
8	29.7	44.7
9	14.7	33.1
10	24.2	42.8
11	13.6	42.5
12	18.8	37.0
13	11.9	15.5
14		
15		
16		
17		
CYCLES 1.	15792.	9648.
AT 2.	15918.	9649
MISS 3.	18128.	9650.

CYCLE NO.	N.C. CONTACT	N.O. CONTACT
INITIAL	45.9	33.5
1	17.7	37.9
2	19.0	36.4
3	27.9	34.1
4	22.8	41.0
5	22.3	38.1
6	16.5	33.8
7	23.1	21.2
8	31.5	30.0
9	16.2	34.0
10	30.1	33.6
11	12.0	43.5
12	17.0	34.0
13	2.9	
14		
15		
16		
17		
CYCLES 1.	9638.	3736.
AT 2.	9671	3737.
MISS 3.	15253.	3738.

CYCLE NO.	N.C. CONTACT	N.O. CONTACT
INITIAL	40.1	49.0
1	22.3	55.1
2	28.7	52.5
3	34.0	51.6
4	15.8	43.1
5	28.4	49.2
6	16.1	56.8
7	21.7	45.4
8	34.7	46.2
9	23.9	38.8
10	17.9	
11	11.9	
12	7.3	
13		
14		
15		
16		
17		
CYCLES 1.	8258.	1220.
AT 2.	8259	2244
MISS 3.	8260.	2316.

CYCLE NO.	N.C. CONTACT	N.O. CONTACT
INITIAL	23.1	36.0
1	21.8	45.0
2	17.0	35.0
3	12.1	25.5
4	22.4	28.0
5	21.9	35.1
6	16.2	22.7
7	22.0	38.1
8	23.0	
9	19.1	
10	16.9	
11	20.8	
12		
13		
14		
15		
16		
17		
CYCLES 1.	1219.	1053.
AT 2.	2189.	1054
MISS 3.	2315.	1073.

CYCLE NO.		N.C. CONTACT	N.O. CONTACT
INITIAL		24.3	52.1
1		24.3	42.8
2		22.1	28.0
3		16.7	25.2
4		16.5	28.3
5		22.0	42.4
6		17.1	41.0
7		22.2	
8		21.0	
9		22.1	
10		19.3	
11		16.3	
12		11.3	
13			
14			
15			
16			
17			
CYCLES	1.	5324.	809.
AT	2.	8259.	824
MISS	3.	8260.	825.

CYCLE NO.		N.C. CONTACT	N.O. CONTACT
INITIAL		27.9	28.8
1		22.3	34.7
2		22.0	
3		31.5	
4		28.2	
5		19.0	
6		18.8	
7		16.0	
8		22.8	
9		28.0	
10		22.0	
11		21.0	
12			
13			
14			
15			
16			
17			
CYCLES	1.	2568.	362.
AT	2.	2586.	363
MISS	3.	2604.	376.

CYCLE NO.		N.C. CONTACT	N.O. CONTACT
INITIAL		46.0	54.2
1		28.9	41.2
2		23.6	47.1
3		27.0	43.9
4		24.3	43.1
5		16.1	49.8
6		23.2	51.9
7		19.4	
8		20.2	
9		27.1	
10		27.7	
11		27.4	
12			
13			
14			
15			
16			
17			
CYCLES	1.	2188.	808.
AT	2.	2315.	824
MISS	3.	2316.	825.

CYCLE NO.		N.C. CONTACT	N.O. CONTACT
INITIAL		27.2	33.8
1		21.9	27.5
2		15.8	
3		18.1	
4		23.9	
5		21.8	
6		18.6	
7		19.5	
8		22.5	
9		15.9	
10		13.2	
11			
12			
13			
14			
15			
16			
17			
CYCLES	1.	955.	376.
AT	2.	2070.	377.
MISS	3.	2071.	378.

CYCLE NO.		N.C. CONTACT	N.O. CONTACT
INITIAL		31.0	44.5
1		24.1	44.5
2		21.0	46.2
3		28.0	47.8
4		22.2	49.4
5		26.8	50.2
6		17.7	20.5
7		22.9	41.0
8		8.6	36.2
9			42.4
10			29.0
11			
12			
13			
14			
15			
16			
17			
CYCLES	1.	1400.	2069.
AT	2.	1621.	2070.
MISS	3.	1622.	2071.

CYCLE NO.		N.C. CONTACT	N.O. CONTACT
INITIAL		21.0	41.6
1		21.2	29.0
2		26.0	35.0
3		27.6	31.8
4		21.1	35.8
5		29.0	34.4
6		16.2	34.3
7		22.3	28.1
8		24.7	23.3
9		23.3	
10		28.5	
11			
12			
13			
14			
15			
16			
17			
CYCLES	1.	1998.	1211.
AT	2.	2015.	1212.
MISS	3.	2027.	1213.

CYCLE NO.		N.C. CONTACT	N.O. CONTACT
INITIAL		22.7	34.2
1		22.1	34.0
2		21.5	
3		22.1	
4		24.7	
5		22.1	
6		16.0	
7		22.8	
8		22.0	
9		21.9	
10		17.6	
11			
12			
13			
14			
15			
16			
17			
CYCLES	1.	1670.	376.
AT	2.	1945.	377.
MISS	3.	1989.	378.

CYCLE NO.		N.C. CONTACT	N.O. CONTACT
INITIAL		39.1	29.1
1		21.8	39.2
2		22.0	44.0
3		20.0	32.4
4		22.8	35.1
5		20.8	36.0
6		21.6	26.3
7		23.4	35.3
8		23.2	36.2
9		15.8	51.8
10		21.9	54.9
11			
12			
13			
14			
15			
16			
17			
CYCLES	1.	2069.	1669.
AT	2.	2070.	1694
MISS	3.	2071.	1695.

CYCLE NO.	N.C. CONTACT	N.O. CONTACT
INITIAL	40.9	33.1
1	15.7	33.4
2	26.0	27.3
3	21.0	28.4
4	18.8	26.9
5	22.1	30.2
6	23.2	33.1
7	16.0	16.0
8		16.2
9		23.2
10		15.1
11		18.1
12		
13		
14		
15		
16		
17		
CYCLES 1.	649.	2589.
AT 2.	748.	2605.
MISS 3.	978.	2624.

CYCLE NO.	N.C. CONTACT	N.O. CONTACT
INITIAL	43.1	43.1
1	15.7	32.9
2	18.3	41.6
3	21.2	34.8
4	21.5	34.5
5	28.0	45.2
6		45.0
7		22.0
8		30.7
9		27.1
10		18.6
11		
12		
13		
14		
15		
16		
17		
CYCLES 1.	650.	1865.
AT 2.	678.	1901.
MISS 3.	695.	1938.

CYCLE NO.	N.C. CONTACT	N.O. CONTACT
INITIAL	52.0	47.2
1	32.0	35.1
2	41.0	46.0
3	39.0	42.0
4	37.2	45.0
5	35.0	50.9
6	36.2	44.1
7	40.3	47.6
8	—	42.5
9		43.1
10		38.9
11		44.0
12		34.8
13		51.7
14		
15		
16		
17		
CYCLES 1.	926.	4436.
AT 2.	1085.	13855.
MISS 3.	1102.	14208.

CYCLE NO.	N.C. CONTACT	N.O. CONTACT
INITIAL	36.9	35.0
1	22.0	37.9
2	26.4	36.8
3	21.8	37.1
4	27.1	41.0
5	22.0	18.7
6	23.0	37.2
7	15.9	41.2
8	15.7	29.9
9	6.7	28.4
10	15.2	48.0
11		28.4
12		51.2
13		
14		
15		
16		
17		
CYCLES 1.	1408.	3859.
AT 2.	1664	3860.
MISS 3.	1665.	3861.

CYCLE NO.		N.C. CONTACT	N.O. CONTACT
INITIAL		35.9	34.3
1		18.9	43.4
2		27.6	22.0
3		21.3	21.2
4		25.9	22.0
5		21.0	22.0
6		28.6	21.8
7		7.3	15.9
8		13.5	18.1
9		11.1	24.3
10			18.3
11			17.5
12			
13			
14			
15			
16			
17			
CYCLES	1.	1406.	3351.
AT	2.	1407.	3616.
MISS	3.	1408.	3705.

CYCLE NO.		N.C. CONTACT	N.O. CONTACT
INITIAL		28.1	32.5
1		28.9	22.0
2		16.0	24.1
3		17.1	26.0
4		12.1	24.1
5		16.2	14.2
6		14.2	19.1
7			16.1
8			21.7
9			21.5
10			19.8
11			
12			
13			
14			
15			
16			
17			
CYCLES	1.	590.	1564.
AT	2.	873.	1771.
MISS	3.	963.	1915.

CYCLE NO.		N.C. CONTACT	N.O. CONTACT
INITIAL		35.5	49.8
1		23.2	35.9
2		26.5	28.8
3		26.8	29.0
4		25.9	39.6
5		10.7	30.0
6		20.6	34.1
7		11.4	23.0
8		16.8	11.8
9		11.1	6.7
10		16.4	26.0
11		18.0	
12			
13			
14			
15			
16			
17			
CYCLES	1.	3410.	2004.
AT	2.	3411.	2005.
MISS	3.	3439.	2006.

CYCLE NO.		N.C. CONTACT	N.O. CONTACT
INITIAL		29.8	63.0
1		21.0	55.0
2		16.0	40.7
3		21.2	36.6
4		22.1	41.0
5		19.2	29.2
6		21.2	36.0
7		17.3	34.3
8		19.2	29.5
9		15.3	28.3
10		20.6	36.7
11		15.7	32.4
12			22.7
13			
14			
15			
16			
17			
CYCLES	1.	2602.	4604.
AT	2.	3358.	5210.
MISS	3.	3359.	5553.

CYCLE NO.	N.C. CONTACT	N.O. CONTACT
INITIAL	25.0	49.0
1	16.8	22.2
2	16.8	27.5
3	23.1	29.2
4	15.9	25.3
5	22.4	22.6
6	15.2	20.7
7	16.8	18.1
8	19.4	8.3
9	15.1	8.2
10	10.9	15.2
11		18.9
12		
13		
14		
15		
16		
17		
CYCLES 1.	1914.	1582.
AT 2.	1951.	1842.
MISS 3.	2006.	2251.

CYCLE NO.	N.C. CONTACT	N.O. CONTACT
INITIAL	30.8	1.8
1	28.8	36.4
2	21.2	28.8
3	27.8	29.5
4	27.0	24.0
5	26.0	28.1
6	15.9	21.1
7	23.2	34.8
8	18.8	
9		
10		
11		
12		
13		
14		
15		
16		
17		
CYCLES 1.	1115.	1006.
AT 2.	1195	1007.
MISS 3.	1214.	1008.

CYCLE NO.	N.C. CONTACT	N.O. CONTACT
INITIAL	16.6	47.1
1		17.1
2		36.2
3		43.7
4		35.6
5		21.7
6		34.8
7		40.8
8		41.8
9		28.8
10		26.0
11		
12		
13		
14		
15		
16		
17		
CYCLES 1.	248.	1869.
AT 2.	263.	1884.
MISS 3.	282.	1902.

CYCLE NO.	N.C. CONTACT	N.O. CONTACT
INITIAL	15.4	35.1
1	16.2	
2	17.0	
3	28.6	
4	16.0	
5	14.0	
6	12.4	
7	28.2	
8	15.8	
9	17.0	
10	5.6	
11		
12		
13		
14		
15		
16		
17		
CYCLES 1.	1883.	348.
AT 2.	1884.	349.
MISS 3.	1903.	350.

CYCLE NO.		N.C. CONTACT	N.O. CONTACT
INITIAL		22.8	35.3
1		22.9	34.3
2		27.3	28.9
3		27.9	37.0
4		23.9	34.0
5		21.7	31.6
6			24.6
7			11.3
8			20.5
9			17.2
10			28.6
11			
12			
13			
14			
15			
16			
17			
CYCLES	1.	692.	2038.
AT	2.	746.	2039.
MISS	3.	747.	2040.

CYCLE NO.		N.C. CONTACT	N.O. CONTACT
INITIAL		42.2	46.4
1		17.3	40.9
2		27.8	35.7
3		20.0	27.9
4		24.1	28.0
5		19.4	25.0
6		15.6	27.7
7		16.6	27.0
8		11.1	7.7
9		16.8	43.9
10		21.8	
11			
12			
13			
14			
15			
16			
17			
CYCLES	1.	1500.	1587.
AT	2.	1589.	1588.
MISS	3.	1652.	1589.

CYCLE NO.		N.C. CONTACT	N.O. CONTACT
INITIAL		15.9	34.8
1		29.7	30.0
2		21.7	28.1
3		22.4	26.9
4		23.9	28.0
5		23.6	45.5
6		21.9	19.3
7		11.8	22.1
8			25.0
9			25.2
10			21.7
11			24.0
12			
13			
14			
15			
16			
17			
CYCLES	1.	959.	2181.
AT	2.	1021.	2182.
MISS	3.	1022.	2183.

CYCLE NO.		N.C. CONTACT	N.O. CONTACT
INITIAL		22.0	32.3
1		21.2	39.7
2		15.7	38.9
3		23.5	45.0
4		11.6	45.5
5		21.6	38.5
6			45.4
7			46.8
8			38.0
9			28.4
10			19.4
11			12.8
12			
13			
14			
15			
16			
17			
CYCLES	1.	298.	2708.
AT	2.	484.	2761.
MISS	3.	583.	3069.

CYCLE NO.		N.C. CONTACT	N.O. CONTACT
INITIAL		2.2	43.1
1		2.2	53.6
2		18.8	28.4
3		26.9	39.3
4		26.9	41.7
5		18.8	41.5
6		16.1	27.3
7		24.8	43.0
8		17.0	28.8
9		26.6	16.5
10			27.0
11			38.6
12			
13			
14			
15			
16			
17			
CYCLES	1.	1581.	3229.
AT	2.	1582.	3230.
MISS	3.	1583.	3231.

CYCLE NO.		N.C. CONTACT	N.O. CONTACT
INITIAL		55.6	45.1
1		34.9	58.0
2		23.2	51.7
3		25.6	58.8
4		24.9	55.1
5		29.3	61.7
6		15.6	51.8
7		21.5	61.3
8		31.8	68.7
9		24.2	56.5
10		29.0	57.9
11			61.1
12			57.2
13			21.7
14			28.9
15			28.7
16			
17			
CYCLES	1.	1641.	71213.
AT	2.	1642.	79267.
MISS	3.	1643.	79268.

CYCLE NO.		N.C. CONTACT	N.O. CONTACT
INITIAL		22.4	62.1
1		27.6	56.8
2		35.0	43.8
3		24.4	48.2
4		22.5	48.2
5		28.6	53.5
6		22.0	45.8
7		21.8	52.0
8		20.0	48.1
9		23.2	52.8
10		16.9	52.8
11			63.0
12			53.3
13			51.1
14			45.7
15			37.1
16			
17			
CYCLES	1.	1643.	64691.
AT	2.	1682.	64692.
MISS	3.	1683.	64693.

CYCLE NO.		N.C. CONTACT	N.O. CONTACT
INITIAL		27.8	28.1
1		27.7	24.6
2		16.2	19.9
3		22.3	19.2
4		21.8	29.2
5		22.2	27.1
6		15.6	19.3
7		5.6	18.4
8			19.1
9			21.9
10			15.2
11			28.8
12			
13			
14			
15			
16			
17			
CYCLES	1.	971.	2812.
AT	2.	972.	2813.
MISS	3.	973.	2832.

CYCLE NO.		N.C. CONTACT	N.O. CONTACT
INITIAL		28.1	46.1
1		16.7	47.8
2		14.4	34.7
3		20.2	33.3
4		18.4	34.9
5		20.5	20.3
6		19.6	35.0
7		10.8	43.6
8		16.0	37.8
9		15.6	36.6
10		17.2	37.0
11		17.0	25.9
12		1.8	25.9
13			
14			
15			
16			
17			
CYCLES	1.	630.	3762.
AT	2.	2920.	3782.
MISS	3.	5103.	3783.

CYCLE NO.		N.C. CONTACT	N.O. CONTACT
INITIAL		22.0	54.3
1		33.0	55.3
2		20.2	54.0
3		35.1	52.4
4		31.9	46.8
5		22.3	56.1
6		22.3	42.5
7		20.9	38.8
8		20.5	44.6
9		21.0	36.0
10		16.8	37.1
11		18.5	33.1
12		1.7	24.9
13		1.6	73.2
14			66.1
15			33.9
16			
17			
CYCLES	1.	8619.	9753.
AT	2.	9682.	35443.
MISS	3.	10020.	35450.

CYCLE NO.		N.C. CONTACT	N.O. CONTACT
INITIAL		54.6	28.0
1		36.0	46.1
2		21.0	34.8
3		21.8	21.9
4		19.9	24.0
5		18.2	27.1
6		22.8	28.8
7		40.9	35.3
8		23.1	21.5
9		22.0	16.8
10		21.9	41.8
11		33.4	17.0
12		27.4	30.0
13		34.2	36.0
14		44.0	
15			
16			
17			
CYCLES	1.	20059.	15808.
AT	2.	20070.	15809.
MISS	3.	28578.	15810.

CYCLE NO.		N.C. CONTACT	N.O. CONTACT
INITIAL		39.1	41.1
1		36.0	
2		15.3	
3		16.0	
4		31.8	
5		25.1	
6		16.4	
7		28.2	
8		22.0	
9		28.1	
10		15.7	
11		22.0	
12		41.2	
13			
14			
15			
16			
17			
CYCLES	1.	2500.	20.
AT	2.	2621.	21.
MISS	3.	3763.	39.

CYCLE NO.	N.C. CONTACT	N.O. CONTACT
INITIAL	11.6	7.8
1	38.2	47.8
2	16.0	42.9
3	27.6	39.3
4	16.0	35.5
5	26.7	27.0
6	20.1	26.5
7	21.7	34.0
8	25.7	26.3
9	21.8	30.0
10	26.6	41.7
11	25.1	28.5
12	24.2	28.5
13	22.6	34.0
14	29.8	29.7
15	16.8	35.0
16		
17		
CYCLES 1.	39530.	50471.
AT 2.	40749.	50607.
MISS 3.	41888.	50608.

CYCLE NO.	N.C. CONTACT	N.O. CONTACT
INITIAL	5.4	35.3
1	28.9	25.1
2	13.1	33.9
3	23.7	45.2
4	19.2	27.2
5	15.2	16.3
6	21.4	23.2
7	21.2	20.3
8	17.1	28.6
9	15.7	21.0
10	16.1	12.9
11	15.6	17.6
12		16.1
13		22.3
14		
15		
16		
17		
CYCLES 1.	168.	3819.
AT 2.	1800.	3820.
MISS 3.	2215.	9718.

CYCLE NO.	N.C. CONTACT	N.O. CONTACT
INITIAL	11.0	39.4
1	36.3	32.7
2	18.3	37.0
3	20.7	56.3
4	20.0	28.9
5	15.9	29.5
6	16.6	29.2
7	16.0	28.0
8	16.2	31.8
9	16.4	14.0
10	22.5	16.2
11	11.3	35.4
12	7.9	
13		
14		
15		
16		
17		
CYCLES 1.	6331.	2234.
AT 2.	6340	2590.
MISS 3.	6363.	2591.

CYCLE NO.	N.C. CONTACT	N.O. CONTACT
INITIAL	23.8	38.3
1	36.2	39.2
2	20.2	62.9
3	28.5	38.7
4	23.2	39.8
5	20.7	38.3
6	15.8	28.6
7	23.7	28.4
8	15.8	22.0
9	21.8	41.3
10	11.7	14.7
11	11.2	54.0
12		
13		
14		
15		
16		
17		
CYCLES 1.	3347.	2138.
AT 2.	3348.	2139.
MISS 3.	3349.	2140.

CYCLE NO.	N.C. CONTACT	N.O. CONTACT	CYCLE NO.	N.C. CONTACT	N.O. CONTACT
INITIAL	54.9	37.8	INITIAL	8.6	43.8
1	44.1	45.2	1	38.1	52.3
2	32.0	40.2	2	27.2	61.5
3	30.9	39.9	3	25.0	42.5
4	29.9	28.9	4	20.1	27.3
5	30.8	31.2	5	16.0	63.0
6	33.6	28.0	6	20.1	43.3
7	27.9	20.2	7	21.6	
8	25.0	29.4	8	16.7	
9	19.0	29.0	9	20.8	
10	35.1	12.9	10	18.0	
11	29.1	28.4	11	23.0	
12	12.2	31.8	12	13.0	
13			13	11.5	
14			14		
15			15		
16			16		
17			17		
CYCLES 1.	4850.	3798.	CYCLES 1.	9697.	768.
AT 2.	4874.	3799.	AT 2.	9698.	769.
MISS 3.	4940.	3800.	MISS 3.	9699.	770.

6.7.6 TYPE B RELAYS, NORMAL TEST CONDITIONS WITH I.M. PRODUCTS MEASUREMENTS

The data for the 10 Type B relays that received I.M. products measurements under normal test conditions is given on the following 3 pages. Normal conditions refer to a 3 amp. contact load, 25°C. temperature and a 1 hz actuation rate. I.M. product measurements (in mv. units) are given for both the normally closed (N.C.) contacts and normally open (N.O.) contacts on each relay. The number of cycles at the first, second and third miss of each contact is also given. The number of cycles at which readings were taken are indexed as follows:

1.	18,000 cycles	10.	980,000 cycles
2.	440,000 cycles	11.	1,055,000 cycles
3.	650,000 cycles	12.	1,150,000 cycles
4.	725,000 cycles	13.	1,200,000 cycles
5.	750,000 cycles	14.	1,275,000 cycles
6.	795,000 cycles	15.	1,460,000 cycles
7.	835,000 cycles	16.	1,780,000 cycles
8.	905,000 cycles	17.	1,885,000 cycles
9.	930,000 cycles		

CYCLE NO.	N.C. CONTACT	N.O. CONTACT
INITIAL	2.85	2.73
1	2.63	2.79
2	2.32	2.49
3	2.68	2.81
4	2.62	2.76
5	2.71	2.85
6	2.70	2.81
7	2.71	2.82
8	2.69	2.78
9	2.71	2.82
10	2.70	
11	2.69	
12	2.69	
13	2.70	
14	2.63	
15	2.68	
16	2.58	
17	2.60	
CYCLES 1.	238459.	854506.
AT 2.	2700000.	941527.
MISS 3.	2700000.	955254.

CYCLE NO.	N.C. CONTACT	N.O. CONTACT
INITIAL	2.44	2.70
1	2.43	2.72
2	2.16	2.45
3	2.49	2.79
4	2.50	2.73
5	2.52	2.82
6	2.49	2.77
7	2.51	2.82
8	2.49	2.76
9	2.53	2.81
10	2.49	2.75
11	2.49	2.73
12	2.50	2.80
13	2.50	2.80
14	2.50	2.79
15	2.50	2.80
16	2.42	
17	2.40	
CYCLES 1.	1646888.	934459.
AT 2.	1997570.	1618311.
MISS 3.	1997577.	1618314.

CYCLE NO.	N.C. CONTACT	N.O. CONTACT
INITIAL	2.43	2.45
1	2.48	2.50
2		
3		
4		
5		
6		
7		
8		
9		
10		
11		
12		
13		
14		
15		
16		
17		
CYCLES 1.	377804.	381848.
AT 2.	377903.	381849.
MISS 3.	377904.	381850.

CYCLE NO.	N.C. CONTACT	N.O. CONTACT
INITIAL	2.72	2.70
1	2.78	2.78
2	2.43	2.48
3	2.81	2.81
4	2.75	2.75
5	2.83	2.80
6	2.82	2.79
7	2.84	2.82
8	2.78	2.77
9	2.84	2.83
10	2.81	2.75
11	2.79	2.75
12	2.81	2.79
13	2.82	2.80
14	2.79	2.81
15	2.52	2.80
16	2.78	2.71
17	2.72	2.71
CYCLES 1.	2700000.	999665.
AT 2.	2700000.	2064585.
MISS 3.	2700000.	2065524.

CYCLE NO.		N.C. CONTACT	N.O. CONTACT
INITIAL		2.30	2.39
1		2.33	2.46
2			2.20
3			2.49
4			2.43
5			2.49
6			2.45
7			2.49
8			2.46
9			2.49
10			2.44
11			2.43
12			2.48
13			2.51
14			2.50
15			2.50
16			2.48
17			2.43
CYCLES	1.	421108.	508275.
AT	2.	421180.	2226091.
MISS	3.	421186.	2226101.

CYCLE NO.		N.C. CONTACT	N.O. CONTACT
INITIAL		2.21	2.12
1		2.29	2.15
2		2.30	2.21
3		2.31	2.21
4		2.35	2.22
5		2.35	2.24
6		2.33	2.21
7		2.36	2.25
8		2.38	2.28
9		2.36	2.27
10		2.36	2.25
11		2.37	2.27
12		2.33	2.23
13		2.35	2.26
14		2.34	2.22
15		2.36	2.23
16		2.34	2.24
17		2.34	2.22
CYCLES	1.	1818856.	2648522
AT	2.	2700000.	2648823.
MISS	3.	2700000.	2648872.

CYCLE NO.		N.C. CONTACT	N.O. CONTACT
INITIAL		2.37	2.58
1		2.36	2.61
2		2.41	2.61
3		2.39	2.62
4		2.42	
5		2.43	
6		2.42	
7			
8			
9			
10			
11			
12			
13			
14			
15			
16			
17			
CYCLES	1.	807661.	606768.
AT	2.	807686.	653051.
MISS	3.	807698.	694448.

CYCLE NO.		N.C. CONTACT	N.O. CONTACT
INITIAL		2.16	2.10
1		2.19	2.08
2			2.14
3			2.16
4			2.18
5			2.19
6			
7			
8			
9			
10			
11			
12			
13			
14			
15			
16			
17			
CYCLES	1.	423085.	786631.
AT	2.	423114.	786718.
MISS	3.	423119.	786723.

CYCLE NO.		N.C. CONTACT	N.O. CONTACT
INITIAL		2.08	1.99
1		2.12	2.02
2		2.14	2.07
3		2.16	2.03
4		2.18	2.08
5		2.19	2.08
6		2.19	2.07
7		2.17	2.08
8		2.19	2.09
9		2.21	2.08
10		2.19	2.08
11		2.18	
12		2.17	
13		2.19	
14		2.16	
15		2.19	
16		2.15	
17		2.14	
CYCLES	1.	2700000.	1027140.
AT	2.	2700000.	1031319.
MISS	3.	2700000.	1031342.

CYCLE NO.		N.C. CONTACT	N.O. CONTACT
INITIAL		2.81	2.19
1		2.81	2.23
2		2.82	2.29
3		2.82	2.30
4		2.89	2.33
5		2.88	2.32
6		2.85	2.32
7		2.83	2.31
8		2.91	2.35
9		2.90	2.33
10		2.88	2.33
11		2.89	2.31
12		2.84	2.33
13		2.88	2.33
14		2.84	2.31
15		2.87	2.29
16		2.85	
17		2.86	
CYCLES	1.	2700000.	1487905
AT	2.	2700000.	1488675.
MISS	3.	2700000.	1489021.

6.7.7 TYPE B RELAYS, NORMAL TEST CONDITIONS WITH C.R. MEASUREMENTS

The data from the 10 Type B relays which were tested at normal conditions with C.R. measurements is presented on the next 3 pages. The C.R. measurements are given in amps. The codes 1-17 refer to the same numbers of test cycles as those in Subsection 6.7.6.

CYCLE NO.		N.C. CONTACT	N.O. CONTACT
INITIAL		330.0	175.0
1		120.0	45.0
2			330.0
3			
4			
5			
6			
7			
8			
9			
10			
11			
12			
13			
14			
15			
16			
17			
CYCLES	1.	337998.	554397.
AT	2.	338003.	554420.
MISS	3.	338076.	554445.

CYCLE NO.		N.C. CONTACT	N.O. CONTACT
INITIAL		330.0	106.0
1		90.0	140.0
2		170.0	145.0
3		290.0	145.0
4		312.0	111.0
5		328.0	144.0
6		330.0	145.0
7		330.0	156.0
8		246.0	152.0
9		330.0	140.0
10		330.0	142.0
11		330.0	142.0
12		330.0	135.0
13		328.0	140.0
14		330.0	135.0
15		332.0	142.0
16		250.0	
17		335.0	
CYCLES	1.	2700000.	1559662.
AT	2.	2700000.	1564102.
MISS	3.	2700000.	1600644.

CYCLE NO.		N.C. CONTACT	N.C. CONTACT
INITIAL		328.0	205.0
1		150.0	242.0
2		328.0	255.0
3		328.0	230.0
4		328.0	280.0
5		328.0	238.0
6		328.0	310.0
7		328.0	320.0
8		200.0	328.0
9		328.0	286.0
10		328.0	265.0
11		328.0	180.0
12		328.0	130.0
13		328.0	280.0
14		328.0	264.0
15			
16			
17			
CYCLES	1.	1466356.	1466356.
AT	2.	1466357.	1466357.
MISS	3.	1466358.	1466358.

CYCLE NO.		N.C. CONTACT	N.O. CONTACT
INITIAL		321.0	168.0
1		92.0	140.0
2			160.0
3			180.0
4			
5			
6			
7			
8			
9			
10			
11			
12			
13			
14			
15			
16			
17			
CYCLES	1.	253657.	439715.
AT	2.	253703.	586424.
MISS	3.	253709.	691006.

CYCLE NO.		N.C. CONTACT	N.O. CONTACT
INITIAL		330.0	172.0
1		90.0	140.0
2		330.0	200.0
3		310.0	210.0
4		330.0	300.0
5		330.0	270.0
6		330.0	250.0
7		320.0	320.0
8		330.0	315.0
9		330.0	249.0
10		330.0	255.0
11		330.0	315.0
12		330.0	270.0
13		310.0	300.0
14		330.0	255.0
15		330.0	252.0
16		330.0	325.0
17		330.0	330.0
CYCLES	1.	2700000.	1046450.
AT	2.	2700000.	1548543.
MISS	3.	2700000.	4330110.

CYCLE NO.		N.C. CONTACT	N.O. CONTACT
INITIAL		278.0	320.0
1		50.0	50.0
2		75.0	118.0
3		200.0	150.0
4		332.0	321.0
5		334.0	335.0
6		335.0	
7		335.0	
8		280.0	
9		335.0	
10		335.0	
11		160.0	
12		335.0	
13		270.0	
14		305.0	
15		250.0	
16			
17			
CYCLES	1.	815791.	744415.
AT	2.	815792.	745279.
MISS	3.	1630224.	755636.

CYCLE NO.		N.C. CONTACT	N.O. CONTACT
INITIAL		150.0	218.0
1		90.0	200.0
2		328.0	330.0
3		285.0	
4		256.0	
5		328.0	
6		300.0	
7		328.0	
8			
9			
10			
11			
12			
13			
14			
15			
16			
17			
CYCLES	1.	531974.	465100.
AT	2.	565921.	465193.
MISS	3.	861386.	465194.

CYCLE NO.		N.C. CONTACT	N.O. CONTACT
INITIAL		335.0	58.0
1		132.0	84.0
2			110.0
3			
4			
5			
6			
7			
8			
9			
10			
11			
12			
13			
14			
15			
16			
17			
CYCLES	1.	307726.	497030.
AT	2.	307731.	498561.
MISS	3.	307750.	498572.

CYCLE NO.		N.C. CONTACT	N.O. CONTACT
INITIAL		295.0	89.0
1		59.0	289.0
2		320.0	
3		270.0	
4			
5			
6			
7			
8			
9			
10			
11			
12			
13			
14			
15			
16			
17			
CYCLES	1.	666158.	377326.
AT	2.	666218.	377327.
MISS	3.	666301.	377334.

CYCLE NO.		N.C. CONTACT	N.O. CONTACT
INITIAL		187.0	225.0
1		305.0	200.0
2		262.0	328.0
3		310.0	275.0
4		315.0	325.0
5		315.0	241.0
6		242.0	240.0
7		260.0	
8		310.0	
9		200.0	
10		335.0	
11		329.0	
12		334.0	
13		333.0	
14		335.0	
15		334.0	
16		330.0	
17		330.0	
CYCLES	1.	2042481.	720225.
AT	2.	2042493.	728944.
MISS	3.	2042499.	820919.

6.7.8 TYPE C RELAYS, NORMAL TEST CONDITIONS WITH I.M. PRODUCTS MEASUREMENTS

The data for the 10 Type C relays which were tested at normal conditions with I.M. products measurements is presented on the next 3 pages. The I.M. products measurements are given in mv. units. The codes 1-17 refer to the same numbers of test cycles as those in Subsection 6.7.6.

CYCLE NO.		N.C. CONTACT	N.O. CONTACT
INITIAL		2.46	2.82
1		2.43	2.87
2		2.62	2.93
3		2.80	3.02
4		2.70	
5			
6			
7			
8			
9			
10			
11			
12			
13			
14			
15			
16			
17			
CYCLES	1.	441415.	480735.
AT	2.	604284.	645905.
MISS	3.	743248.	661524.

CYCLE NO.		N.C. CONTACT	N.O. CONTACT
INITIAL		2.65	2.70
1		2.59	2.52
2		2.88	
3		3.03	
4		3.00	
5		2.99	
6		2.94	
7		2.99	
8		2.91	
9		2.98	
10		2.88	
11		2.89	
12		2.82	
13		2.93	
14		2.89	
15		2.81	
16		2.86	
17		2.96	
CYCLES	1.	1276242.	233669.
AT	2.	1276243.	236027.
MISS	3.	1885250.	320828.

CYCLE NO.		N.C. CONTACT	N.O. CONTACT
INITIAL		2.45	2.95
1		2.41	2.93
2		2.63	
3		2.69	
4		2.61	
5		2.62	
6		2.63	
7		2.68	
8		2.60	
9		2.62	
10		2.5[illegible]	
11		2.61	
12		2.53	
13		2.5[illegible]	
14		2.56	
15		2.63	
16		2.41	
17		2.62	
CYCLES	1.	2700000.	427798.
AT	2.	2700000.	427924.
MISS	3.	2700000.	427925.

CYCLE NO.		N.C. CONTACT	N.O. CONTACT
INITIAL		2.37	2.91
1		2.30	2.90
2		2.54	3.02
3		2.67	3.13
4		2.58	
5		2.61	
6		2.59	
7		2.64	
8		2.52	
9		2.61	
10		2.52	
11		2.56	
12		2.52	
13		2.60	
14		2.51	
15		2.48	
16		2.61	
17		2.37	
CYCLES	1.	742683.	701045.
AT	2.	2700000.	701047.
MISS	3.	2700000.	701049.

CYCLE NO.		N.C. CONTACT	N.O. CONTACT
INITIAL		2.42	2.67
1		2.33	2.68
2		2.53	2.82
3		2.65	2.93
4		2.61	2.88
5		2.61	2.83
6		2.59	2.88
7		2.65	2.91
8		2.55	2.80
9			
10			
11			
12			
13			
14			
15			
16			
17			
CYCLES	1.	552163.	908038.
AT	2.	606763.	908041.
MISS	3.	926650.	908044.

CYCLE NO.		N.C. CONTACT	N.O. CONTACT
INITIAL		2.89	2.88
1		2.82	2.90
2		3.08	
3		3.07	
4		3.08	
5		3.00	
6		3.03	
7		3.01	
8		3.01	
9		2.99	
10			
11			
12			
13			
14			
15			
16			
17			
CYCLES	1.	338446.	7240.
AT	2.	944991.	230426.
MISS	3.	951605.	247327.

CYCLE NO.		N.C. CONTACT	N.O. CONTACT
INITIAL		2.67	2.73
1		2.55	2.73
2			
3			
4			
5			
6			
7			
8			
9			
10			
11			
12			
13			
14			
15			
16			
17			
CYCLES	1.	281859.	138969.
AT	2.	309909.	138970.
MISS	3.	424230.	250593.

CYCLE NO.		N.C. CONTACT	N.O. CONTACT
INITIAL		2.61	2.54
1		2.62	2.49
2		2.71	2.59
3		2.72	2.58
4		2.80	2.65
5		2.65	2.55
6		2.80	2.59
7		2.82	2.55
8		2.63	2.60
9		2.83	2.60
10		2.88	2.63
11		2.78	2.62
12		2.79	2.62
13		2.68	2.61
14		2.69	
15		2.72	
16		2.78	
17		2.77	
CYCLES	1.	222651.	1041993.
AT	2.	2700000.	1211242.
MISS	3.	2700000.	1215858.

CYCLE NO.	N.C. CONTACT	N.O. CONTACT
INITIAL	2.34	2.53
1	2.28	2.51
2	2.41	2.55
3	2.41	
4	2.42	
5	2.33	
6	2.46	
7	2.42	
8	2.45	
9	2.42	
10	2.34	
11	2.42	
12	2.36	
13	2.36	
14	2.38	
15	2.35	
16	2.32	
17	2.41	
CYCLES 1.	2700000.	594657.
AT 2.	2700000.	632681.
MISS 3.	2700000.	632994.

CYCLE NO.	N.C. CONTACT	N.O. CONTACT
INITIAL	2.85	2.58
1	2.78	2.61
2	2.96	
3	2.92	
4	2.91	
5	2.82	
6	2.92	
7	2.90	
8	2.94	
9	2.93	
10	2.98	
11	2.91	
12	2.91	
13	2.86	
14	2.89	
15	2.89	
16	2.89	
17	2.91	
CYCLES 1.	1976747.	284633.
AT 2.	1976749.	365078.
MISS 3.	1976751.	365080.

6.7.9 TYPE C RELAYS, NORMAL TEST CONDITIONS WITH C.R. MEASUREMENTS

The data from the 12 Type C relays which were tested at normal condition with C.R. measurements is presented in the next 3 pages. The C.R. measurements are given in amps. The codes 1-17 refer to the same numbers of test cycles as those in Subsection 6.7.6.

CYCLE NO.	N.C. CONTACT	N.O. CONTACT
INITIAL	52.0	12.0
1	34.0	29.0
2	38.0	
3		
4		
5		
6		
7		
8		
9		
10		
11		
12		
13		
14		
15		
16		
17		
CYCLES 1.	510234.	412467.
AT 2.	589069.	431579.
MISS 3.	618979.	432012.

CYCLE NO.	N.C. CONTACT	N.O. CONTACT
INITIAL	36.0	21.0
1	11.0	17.0
2	11.0	36.0
3	37.0	60.0
4	23.0	43.0
5	34.0	47.0
6	50.0	57.0
7	28.0	45.0
8	26.0	
9	31.0	
10	35.0	
11	45.0	
12	22.0	
13	37.0	
14	35.0	
15	34.0	
16	31.0	
17	7.5	
CYCLES 1.	1149528.	681455.
AT 2.	2700000.	760476.
MISS 3.	2700000.	837284.

CYCLE NO.	N.C. CONTACT	N.O. CONTACT
INITIAL	35.0	33.0
1	11.0	28.0
2		
3		
4		
5		
6		
7		
8		
9		
10		
11		
12		
13		
14		
15		
16		
17		
CYCLES 1.	294166.	324539.
AT 2.	294169.	324540.
MISS 3.	294170.	324973.

CYCLE NO.	N.C. CONTACT	N.O. CONTACT
INITIAL	46.0	34.0
1	12.0	21.0
2	41.0	38.0
3	60.0	48.0
4	43.0	49.0
5	53.0	53.0
6	44.0	36.0
7	27.0	
8	47.0	
9	35.0	
10	12.0	
11	45.0	
12	41.0	
13	20.0	
14	44.0	
15	34.0	
16	34.0	
17		
CYCLES 1.	1927680.	638205.
AT 2.	1927681.	741818.
MISS 3.	1927682.	816069.

CYCLE NO.		N.C. CONTACT	N.O. CONTACT
INITIAL		44.0	57.0
1		28.0	22.0
2		34.0	43.0
3		25.0	42.0
4		40.0	44.0
5		30.0	58.0
6		33.0	45.0
7		44.0	41.0
8		35.0	49.0
9		39.0	25.0
10		33.0	
11		32.0	
12		20.0	
13		21.0	
14		21.0	
15		8.5	
16		3.4	
17		4.5	
CYCLES	1.	2700000.	696198.
AT	2.	2700000.	737573.
MISS	3.	2700000.	959993.

CYCLE NO.		N.C. CONTACT	N.O. CONTACT
INITIAL		12.0	59.0
1		20.0	11.0
2		12.0	26.0
3		34.0	
4		32.0	
5		20.0	
6		20.0	
7		31.0	
8		27.0	
9		21.0	
10		42.0	
11		34.0	
12		12.0	
13		27.0	
14		43.0	
15		28.0	
16		36.0	
17		1.0	
CYCLES	1.	2700000.	483613.
AT	2.	2700000.	483868.
MISS	3.	2700000.	484046.

CYCLE NO.		N.C. CONTACT	N.O. CONTACT
INITIAL		42.0	44.0
1		11.0	22.0
2		11.0	
3			
4			
5			
6			
7			
8			
9			
10			
11			
12			
13			
14			
15			
16			
17			
CYCLES	1.	478291.	368477.
AT	2.	525573.	368478.
MISS	3.	525575.	368479.

CYCLE NO.		N.C. CONTACT	N.O. CONTACT
INITIAL		20.0	11.0
1		20.0	10.0
2		22.0	54.0
3		20.0	
4		27.0	
5		22.0	
6		32.0	
7		34.0	
8		28.0	
9		22.0	
10		37.0	
11		34.0	
12		22.0	
13		22.0	
14		11.0	
15		33.0	
16			
17			
CYCLES	1.	1497558.	613119.
AT	2.	1497559.	613121.
MISS	3.	1497560.	613122.

CYCLE NO.		N.C. CONTACT	N.O. CONTACT
INITIAL		21.0	22.0
1		83.0	24.0
2		16.0	36.0
3		21.0	50.0
4		29.0	34.0
5		33.0	37.0
6		22.0	43.0
7		22.0	45.0
8		30.0	45.0
9		34.0	46.0
10		22.0	34.0
11		20.0	
12		29.0	
13		53.0	
14		82.0	
15		21.0	
16			
17			
CYCLES	1.	1525383.	1006277.
AT	2.	1651323.	1006680.
MISS	3.	1706172.	1006681.

CYCLE NO.		N.C. CONTACT	N.O. CONTACT
INITIAL		28.0	22.0
1		35.0	59.0
2		54.0	58.0
3		34.0	
4		50.0	
5		45.0	
6		53.0	
7		59.0	
8		55.0	
9		22.0	
10		48.0	
11		50.0	
12		53.0	
13		11.0	
14		68.0	
15		11.0	
16		8.0	
17		34.0	
CYCLES	1.	393511.	238910.
AT	2.	535279.	471302.
MISS	3.	2700000.	540555.

CYCLE NO.		N.C. CONTACT	N.O. CONTACT
INITIAL		29.0	29.0
1		21.0	53.0
2		43.0	
3		42.0	
4		54.0	
5		37.0	
6		45.0	
7		44.0	
8		65.0	
9		32.0	
10		12.0	
11		10.0	
12		54.0	
13		12.0	
14		11.0	
15		54.0	
16		62.0	
17		54.0	
CYCLES	1.	1563620.	153067.
AT	2.	1563620.	168534.
MISS	3.	2700000.	168535.

CYCLE NO.		N.C. CONTACT	N.O. CONTACT
INITIAL		28.0	42.0
1		21.0	11.0
2		33.0	
3		22.0	
4		28.0	
5		32.0	
6		23.0	
7		28.0	
8		29.0	
9		22.0	
10		34.0	
11		31.0	
12		45.0	
13		36.0	
14		35.0	
15		11.0	
16		10.0	
17		11.0	
CYCLES	1.	2700000.	405931.
AT	2.	2700000.	405932.
MISS	3.	2700000.	405934.